NOLOGY DEPT:

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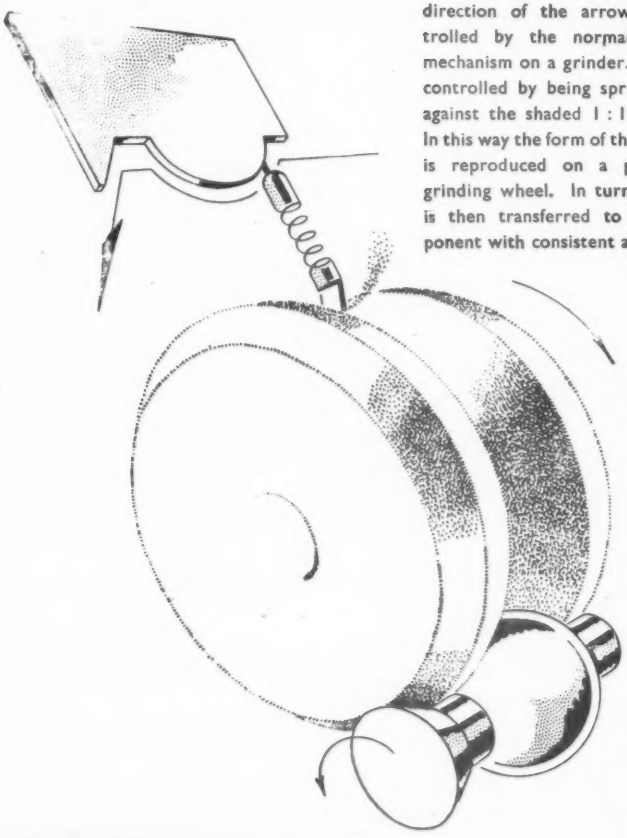
GOOD FORM



The path of the Dianyf tool in the direction of the arrows is controlled by the normal dressing mechanism on a grinder. It is also controlled by being spring loaded against the shaded 1 : 1 template. In this way the form of the template is reproduced on a production grinding wheel. In turn the form is then transferred to the component with consistent accuracy.

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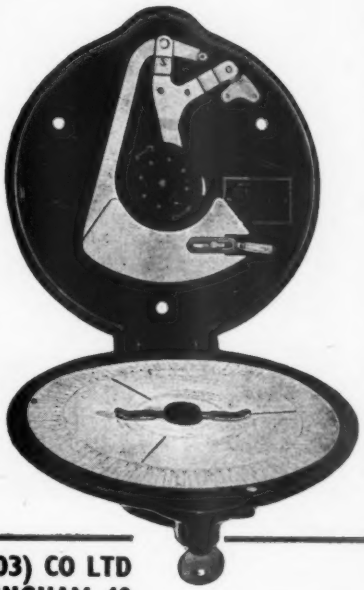
FOR REGULARITY OF FINISH

The illustration shows pressure die cast components for Servis Recorders. Our customer says, "We have been using your aluminium pressure castings for upwards of twenty years and we have found nothing to surpass them in regularity of finish. Our instruments are in use in all parts of the world and we have never yet had a single complaint regarding the parts you make for us. We have also come to appreciate and to rely on your Drawing Office and Design Staff, who have always been most helpful in the development of new types, and we look forward to continuing our co-operation with you for many years to come."

Extract from letter received from Servis Recorders, Gloucester.



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L163

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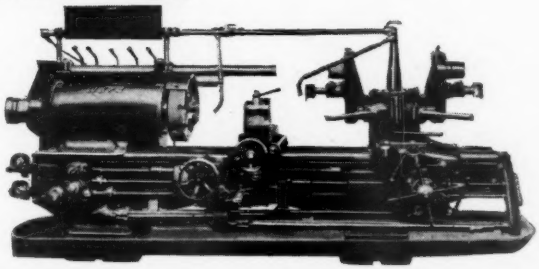
Ward machines are designed and built to get the best out of tungsten carbide, their metal removing capacity being limited only by the cutting tools used.



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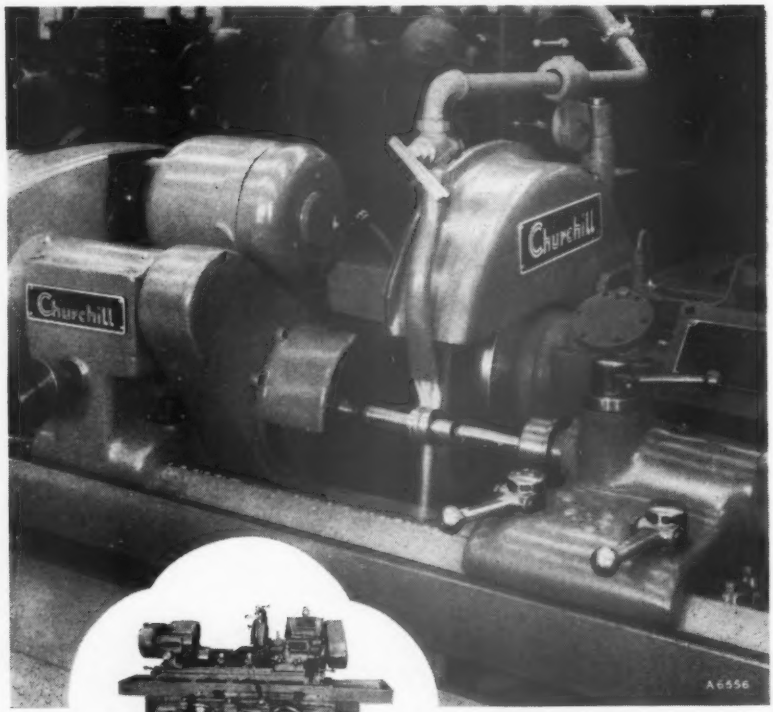

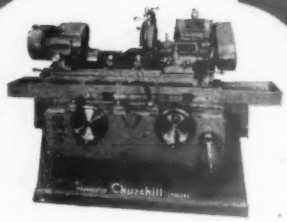

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The Churchill 6in. swing plain grinder has a reputation for accuracy and high output. The latest Model AW as illustrated—built in two sizes, 6in. × 18in. and 6in. × 34in.—can be supplied as a non-automatic or fully automatic plain grinder. Full details on application.

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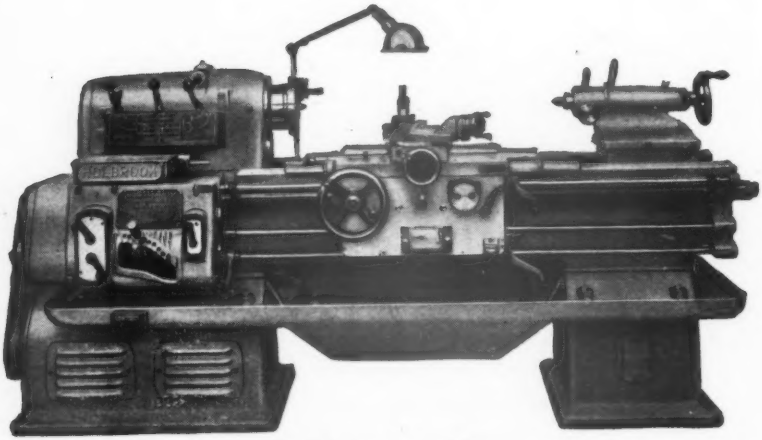
PRECISION TOOL-ROOM LATHES



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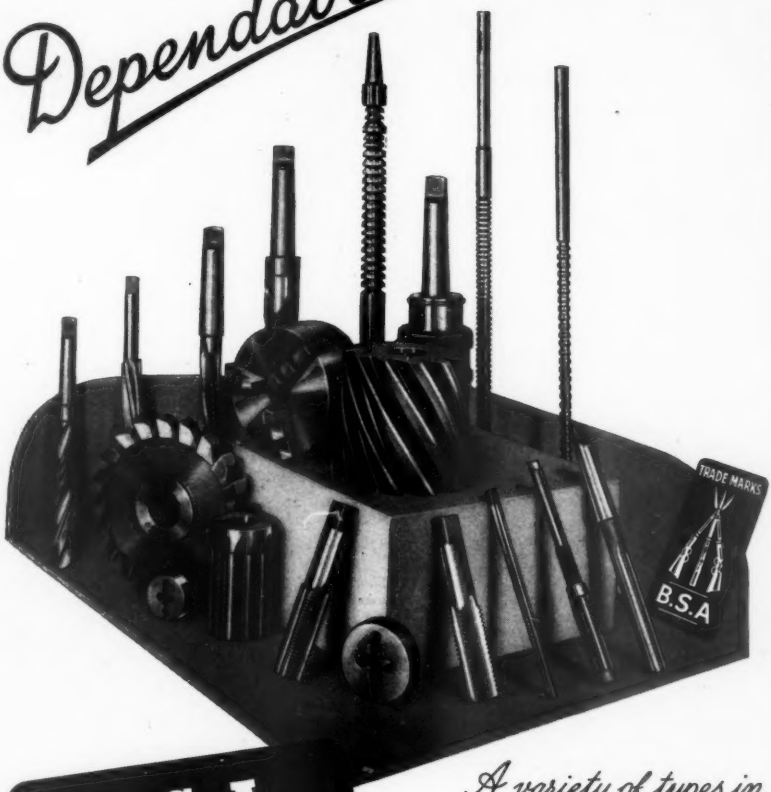

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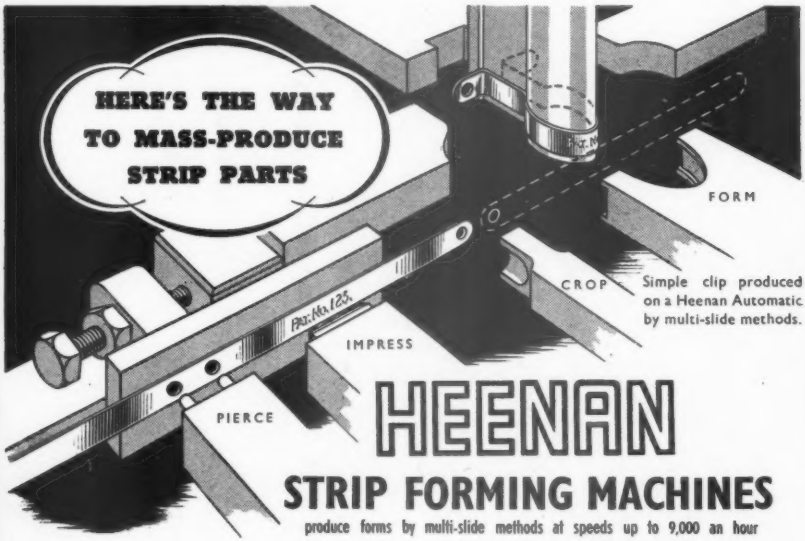
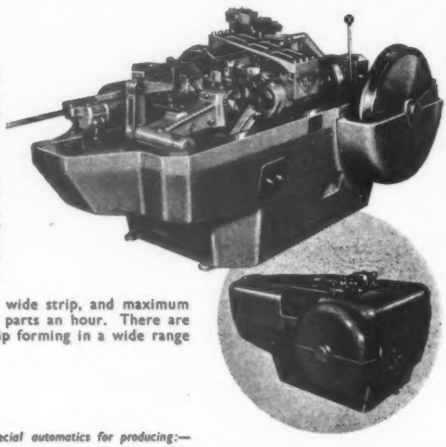


Simple clip produced on a Heenan Automatic by multi-slide methods.

HEENAN
STRIP FORMING MACHINES

produce forms by multi-slide methods at speeds up to 9,000 an hour



Just imagine one of your components in place of the clip shown above—see how simply it can be produced from coiled stock in a single pass through the machine. You could probably cut out six or seven separate press operations and obtain a higher output from a single Heenan Automatic.

On Heenan Automatic Strip Forming Machines multi-slide tooling can be used in the ram die set for piercing, embossing, blanking, etc., and two- or three-stage forming can be employed at the final forming station. Special attachments are available for lock seaming, can seaming, transferring and ring setting.

The model S.103A, illustrated, takes 1½" wide strip, and maximum blank length is 4". Output is up to 9,000 parts an hour. There are other Heenan Automatics for wire and strip forming in a wide range of sizes. Send for details to-day.

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Photograph by courtesy of Brook Motors Ltd., Huddersfield

BORING AND TURNING TOOLS

Wimet tools are boring and facing 18¼" dia. cast-iron motor end shields in a cycle time per component of 7½ minutes — the 4½" dia bore is roughed, outside dia. turned, bearing boss and spigot rough faced in the first operation. Finish facing and reaming is completed in the second operation. Roughing tools machine 80 ends per regrind, and finishing tools only require regrinding every 300 ends — typical Wimet performance.

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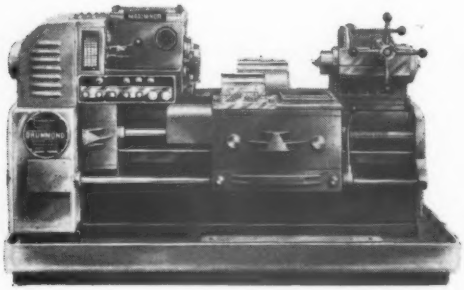
FULLY AUTOMATIC JUNIOR MULTI-TOOL LATHE
FOR THE SMALLER RANGE OF WORKPIECES



CAPACITIES : 6 × 18in. ; 6 × 30in. ; 6 × 42in.

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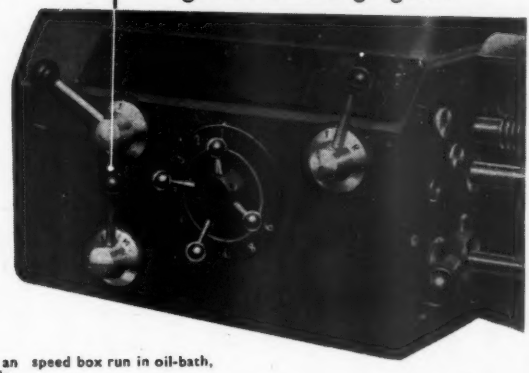
No necessity to remove guards or change gears

This is only one of many advanced features of this modern S.S. & S.C. Lathe, a few others being:



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★ Apron fitted with snap action controls, all fully interlocking and fool-proof.

★ 18 speeds 27-757 r.p.m., 3 h.p motor

★ All gears in apron an speed box run in oil-bath, with oil sight levels.

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★ Patented system of replacing Vee belts without removing spindle.

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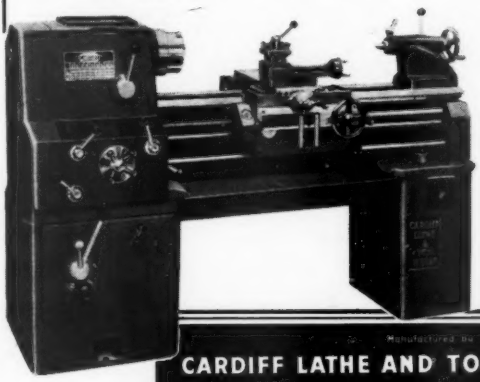

MODEL 7in. × 40in. and 7in. × 60in. } 14 SWING

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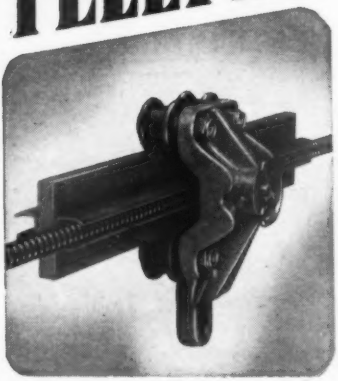

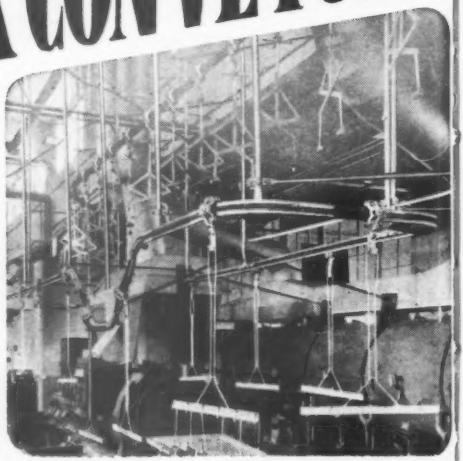

For "Medium Duty" Conveying—the chain conveyor shown in the top illustrations is designed to carry substantial loads. The principle of chain and guides is clearly shown in the top right inset, whilst adaption to a platform conveyor is apparent from the lower right inset.

For "Light Duty" Conveying—the unique cable conveyor shown in the lower illustration, The inset illustration exemplifies the simple and sound construction used in manufacture. Both the above types of conveyors are readily constructed from standard "off the shelf" units, which when assembled can form a "tailor-made" conveyor for your particular works. Inherent features of the Teleflex systems are, therefore :—

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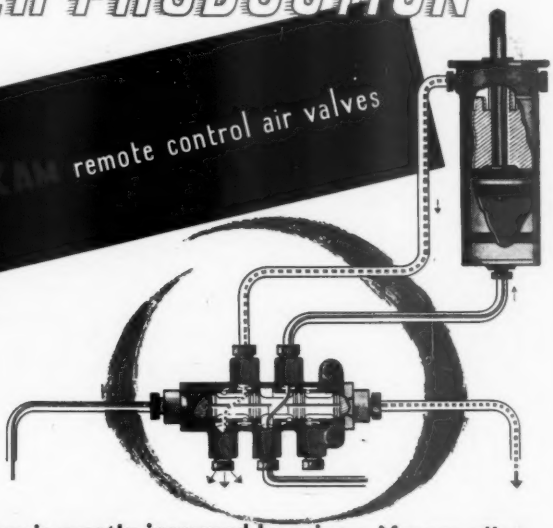

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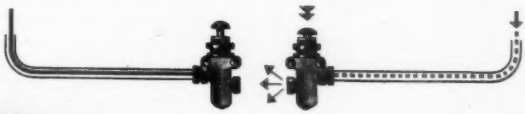

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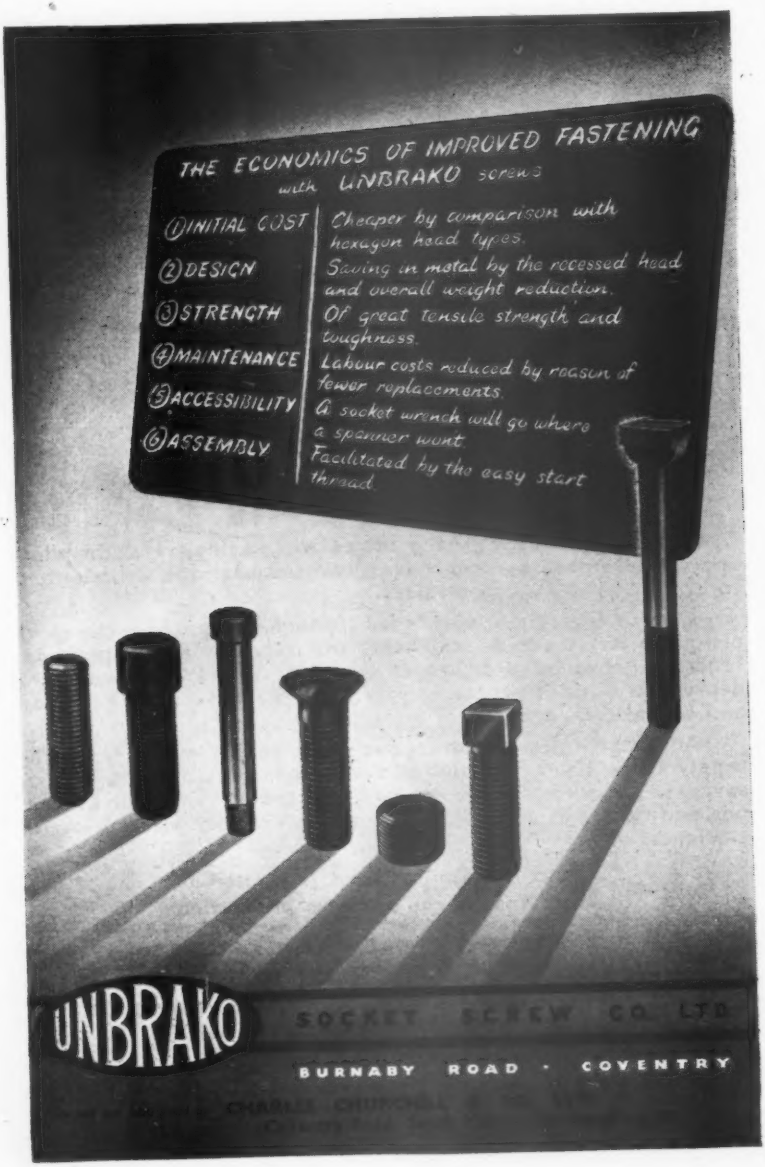
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THE JOURNAL OF

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The Institution of Production Engineers does not accept responsibility for any statements made or opinions expressed in any papers published in the Journal of the Institution.

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INSTITUTION NOTES

August, 1951

HARROGATE CONFERENCE, 28th June/1st July, 1951

Approximately five hundred people, including members from Australia and India, gathered in Harrogate for the Second National Conference organised by the Institution, the theme of which was " How to Facilitate the Introduction of Improved Methods into Industry." The work of the Conference was carried on through addresses by men of high standing, by discussion groups, and by case studies.

Without doubt, one of the most inspiring addresses ever given to the Institution was that by Dr. C. F. Garbett, the Lord Archbishop of York, at the opening Dinner, when in dwelling on the ethics of industry and the human factor, he gave his audience much food for thought.

Light was thrown on the differences between British and American industrial conditions by Mr. W. Hamilton Walter, Assistant Chief of the Economic Co-operation Administration Mission to the U.K., who spoke at the first plenary session in place of the Hon. William L. Batt, Minister-in-Charge, E.C.A. Mission to London, who had been recalled to Washington to report to Congress.

Sir Norman Kipping, Joint Secretary of the Anglo-American Council on Productivity and Director-General, Federation of British Industries, put much factual information before the meeting, dealing with the nation's economic situation. The part that the Trade Unions must play in our drive for prosperity was outlined by Mr. Lincoln Evans, Joint Chairman of the Anglo-American Council on Productivity and General Secretary, Iron and Steel Confederation. He emphasised that we have gone about as far as we can in slicing and sharing out the " national cake," and a better standard of living can come only by getting a larger " cake " through increased production.

When Sir Ewart Smith, Technical Director, I.C.I., Ltd., spoke at the final plenary session, the Conference members received another outstanding address, giving them much to take away for consideration.

DISCUSSION GROUPS

Most of the time was taken up by the discussion groups of which there were ten, so that there were always different groups in session simultaneously. Whilst certain of the subjects, e.g., training and incentives, were obviously intended to deal with personnel, most of the subjects were aimed at technology and processes. However, in all discussion groups there was a marked tendency to discuss the human factor in the problem. This tendency came without direction from the main speakers and chairmen, and is perhaps indicative of conditions prevailing today, when one of the main obstacles to improvements in industry is the human attitude, on the part of workers and management alike, to resist changes.

In view of the importance of the Conference, it is hoped to publish a full report in the September issue of the Journal.

PRODUCTION CONVENTION AT SYDNEY

An Engineering Production Convention, held at the Sydney University over four days and concluding on May 24th, 1951, chose as its theme : " Production Economy Through Basic Engineering Standards." The interest shown surprised the organisers and all meetings were well attended, the number who registered amounting to 460, in addition to many interstate visitors. The Convention was fortunate in having also several visitors from the United Kingdom.

The Convention was organised by a committee on which the Sydney Section of the I.Prod.E. was represented by two members and the Institution took an active part in the proceedings.

The credit for the success of the Convention was due to Mr. C. A. Gladman, M.I.Prod.E., who conceived the idea, and Mr. N. A. Esserman, M.I.Prod.E., under the Chairmanship of Mr. A. S. Plowman (Institution of Engineers (Australia) and Secretaryship of Mr. Jas. Moore of the Standards Association of Australia.

The opening ceremony took place in the Great Hall of the University and was performed by the Governor of New South Wales, Lieut.-Gen. Sir John Northcott, K.C.M.G., C.B., M.V.O.

Opening addresses were given by :

Mr. S. J. Harley, M.I.Prod.E., Head of British Delegation to American–British–Canadian Conference on Unification of Engineering Standards.

The late Mr. E. J. Bryant, Head of American Delegation. (Read by Mr. E. C. Parkinson, M.I.Prod.E.)

Mr. J. G. Morrow, Head of Canadian Delegation. (Read by Mr. O. F. MacMahon.)

Mr. F. H. Rolt, M.I.Prod.E., Superintendent, Metrology Division, National Physical Laboratory, England. (Recorded).

The following papers were submitted :

(1) " Limits and Fits," by J. Piggott, M.I.Prod.E. General Manager, Coventry Gauge & Tool Co. (Aust.) Pty. Ltd.

(2) " Gauging Principles," by N. A. Esserman, B.Sc., M.I.Prod.E., F.Inst.P., A.M.I.E.Aust. Chief, Division of Metrology, National Standards Laboratory, C.S.I.R.O., Sydney.

(3) " Screw Threads," by L. W. Nickols, B.Sc.(Eng.), A.M.I.Mech.E., A.M.I.Prod.E. (Commissioned by Mr. C. A. Gladman). Principal Scientific Officer, Metrology Division, National Physical Laboratory, Teddington, England.

(4) " Surface Finish," by R. E. Reason, A.R.C.S. Messrs. Taylor, Taylor & Hobson Ltd., Leicester, England.

(5) " Drawing Practice," by Major J. F. Wrigglesworth, Army Design Department, Australia.

(6) " Industrial Applications," by C. A. Gladman, B.Sc.(Eng.-Hons.).Lond., A.C.G.I., A.M.I.Mech.E., M.I.Prod.E., M.I.E.D. Principal Research Officer, Division of Metrology, C.S.I.R.O., Sydney.

These Papers will be published in book form and will include the discussions which were taken down on a wire recorder.

Visits were arranged to the National Standards Laboratory, Cockatoo Dockyard and Telephone and Electrical Industries.

At the concluding meeting one resolution passed was to the effect that the Institution of Engineers (Aust.) and the Australian Sub-Council of the Institution of Production Engineers jointly establish a co-ordinating committee to stimulate interest and further the matters covered by the Convention.

I. PROD. E. DINNER IN TORONTO

The Institution is pleased to learn that as a result of the initiative and enthusiasm shown by members resident in Canada and the U.S.A., a Temporary Committee has been elected to discuss the formation of a Canadian/U.S.A. Section, the Chairman being Mr. E. A. Young, Associate Member, and the Hon. Secretary, Mr. T. H. Beard, Student.

The first social activity of this group took the form of an informal dinner held at the Royal York Hotel, Toronto, on 8th June last, with the object of providing not only an opportunity for members in Canada and U.S.A. to meet each other, but also to offer a friendly welcome to members from Great Britain who were visiting the International Trade Fair.

This was a most successful occasion, and will, it is hoped, be the forerunner of many others. The photograph on the following page shows those who attended the dinner.

Front Row (left to right): R. J. White ; G. N. Johnson ; F. D. H. Ronald ; R. E. Garner.

Centre (left to right): T. H. Beard (Hon. Sec.) ; R. Nelson ; Sir Holland Goddard (visitor) ; E. A. Young (Chairman) ; J. B. S. Gabriel (visitor) ; R. B. Spiro ; W. M. Buchanan.

Back Row (left to right): G. E. Bausor ; J. Malcolm ; D. E. Furnis ; W. L. Simms (visitor) ; J. E. Oram (visitor) ; S. S. Pritchard ; S. Radcliffe (visitor) ; H. A. Turner.

WOLVERHAMPTON PRODUCTIVITY GROUP

Arising from the Wolverhampton Graduate Section Conference held in January last, a Measurement of Productivity Group has been set up under the Chairmanship of Mr. H. Burke. Several of the leading firms in the area are participating, and the Group hopes shortly to issue a report on its findings.

FULL-TIME (SANDWICH) COURSES IN THE TECHNOLOGY OF PRODUCTION ENGINEERING

The following notice has been issued by the Regional Advisory Council for Higher Technological Education in London and the Home Counties :

1. Provided that suitable arrangements can be made with industry for the release of a sufficient number of students, courses will be available in the Session 1951–52, beginning in September 1951, at the following centres :

ENFIELD TECHNICAL COLLEGE, Queensway, Ponders End (Telephone : HOWARD 1126–8.)
Principal: R. McCrae, B.Sc., M.I.Mech.E.

SOUTH EAST LONDON TECHNICAL COLLEGE, Lewisham Way, S.E.4. (Telephone : TIDEWAY 1421–2.)
Principal: F. H. Reid, B.Sc.(Eng.)., Wh.Ex., M.I.Mech.E., M.I.Mar.E.

KINGSTON-UPON-THAMES TECHNICAL COLLEGE, Kingston Hall Road, Kingston. (Telephone : KINGSTON 1204–5.)
Principal: J. W. Archer, B.Sc.

BOROUGH POLYTECHNIC, Borough Road, S.E.1. (Telephone : WATERLOO 7654.)
Principal: D. H. Ingall, D.Sc., F.R.I.C., F.Inst.P.

N.B.—The course at the Borough Polytechnic is designed primarily for persons employed in the *electrical* or *radio* manufacturing industries.

It is hoped that the experience gained in 1951–52 will justify an extension in 1952–53, and the CROYDON POLYTECHNIC and SOUTH EAST ESSEX TECHNICAL COLLEGE, Longbridge Road, Dagenham, have been suggested as additional centres.

2. All interested, whether as employers, officers of trade unions, or prospective students, are invited to get into touch with one or other of the colleges named for further particulars including qualifications for entry, curriculum, fees, timetable and so forth. Within the broad framework of the scheme each college makes its own arrangements.

3. The courses will be of at least three years' duration, about half the time being spent in the factory and half in the college. They will, in general, be " industrially based," i.e., those attending will be employed persons released from industry specifically for the purpose. The underlying purpose behind the teaching of all the engineering subjects will be to foster in the student the attitude of mind characteristic of the efficient production engineering in an engineering undertaking. The teachers in charge of the work will be mainly graduates who have themselves had substantial experience, in an executive capacity, in the control of production.

4. Firms releasing men for these courses are expected to ensure that their practical experience is systematically and efficiently organised in each of the three years in accordance with a progressive scheme. It may be difficult for a small firm with limited resources to do this and every possible encouragement should be given to the formation of groups of firms who can arrange a comprehensive practical training co-operatively. Co-operation among firms on these lines has been arranged successfully in the Enfield area and

should be possible elsewhere if the initiative is taken by the college or by an individual member firm of the local engineering employers association.

5. The qualifications for entry will, in most instances, be similar to those required for admission to a course for a first degree in engineering at the University of London.

6. Success in the course will carry with it exemption from Parts I and II of the Associate Membership Examination of the Institution of Production Engineers.

SCHOFIELD SCHOLARSHIP, 1951

Mr. F. W. Walton, Graduate, winner of the second Schofield Scholarship for 1951, left Liverpool for the United States on 23rd May last. This photograph, taken aboard s.s. "Nova Scotia," shows Mr. F. W. Whitehead, President of the Liverpool Section, conveying to Mr. Walton the Institution's good wishes for a successful trip.

THE DAVIS AWARD, 1950 The Douglas D. Davis Award for 1950, has been awarded to Mr. K. L. Pickett, Graduate, of Coventry, for his paper "Design and Application of Tungsten Carbide to Blanking and Piercing Press Tools."

BIRTHDAY HONOURS The Institution offers sincere congratulations to Mr. S. R. Howes, Member, and Mr. W. R. Snell, Member, on whom H.M. The King has been pleased to confer the O.B.E. and the M.B.E. respectively. Mr. Howes, who is a member of the Sheffield Section Committee, is Director

and General Works Manager of Samuel Fox & Co. Ltd., Sheffield, and Mr. Snell is Assistant Works Manager of Ruston & Hornsby, Ltd., Lincoln.

NEWS OF MEMBERS

Mr. L. L. Allen, Member, has been appointed Head of the Engineering Department at the Hendon Technical College.

Mr. W. H. Brown, Associate Member, has been appointed Principal of the Rotherham Technical College.

Mr. S. R. Chatterjee, Associate Member, is now Assistant Superintendent of Development (Weapons) at the Technical Development Establishment (Weapons), Kanpur, U.P.

Mr. D. C. Collins, Associate Member, has joined the Board of Directors of Westland Aircraft Ltd., as Works Director.

Mr. W. Gibson Bennett, Member, is now Works Manager at the Climax Rock Drill & Eng. Works Ltd., Carn Brea, Cornwall.

Mr. N. C. van Bergen van der Grijp, Associate Member, is now General Manager at IKI-Plastics Ltd. (Internationale Kunststoffen Industrie N.V.), Voorschoten, Holland.

Mr. J. G. Lloyd, Intermediate Associate Member, has now transferred from the London Office of Vickers-Armstrongs Ltd., to their Elswick Works, Newcastle-on-Tyne, where he is Manager, Printing Machinery Production.

Mr. O. G. Mears, Associate Member, is now Chief Process Engineer with the North British Locomotive Co. Ltd., Glasgow.

Mr. J. F. Nash, Associate Member, has taken up an appointment as Chief Engineer with Crypton Equipment Ltd., Bridgwater, Somerset.

Mr. J. North, Associate Member, is leaving England this month to take up an appointment with Messrs. Bayley & Grimster Ltd., Melbourne, Australia.

Mr. A. H. Pearson, Member, has been appointed a Local Director of Millspaugh Ltd., and full Director of C. A. Harnden Ltd., Hyde (a subsidiary of Millspaugh).

Mr. V. H. Pring, Member, has been appointed Managing Director of Anglo-Rhodesian Steel Products, Lusaka, Northern Rhodesia.

Mr. Max Samuely, Associate Member, has now moved from Canada to Los Angeles, and is Senior Designer on special projects with the Allen Engineering Corporation of Hollywood.

Mr. L. J. Service, Associate Member, is now Senior Assistant in Engineering at the Newport (Mon.) Technical College.

Mr. R. F. Brown, Graduate, is now a Contracts Engineer in the Technical Department of Kroy Refrigeration Ltd., Birmingham.

Mr. D. Hitchings, Graduate and Mr. T. L. Isaacs, Graduate, have joined The Glacier Metal Co., Alperton, as Production Engineers.

Mr. F. S. Langton, Graduate, is now Assistant Works Manager at Air Pumps Ltd., Wimbledon.

Mr. M. G. Mackay, Graduate, has left England to take up an appointment as Production Engineer with the Burmah Oil Co. Ltd., Upper Assam, India.

Mr. J. S. Manku, Graduate, is now Assistant Engineer in the Indian Agricultural Research Institute, Ministry of Food & Agriculture, Government of India, New Delhi.

BRITISH STANDARDS The following standards have recently been issued, and may be obtained from the British Standards Institution, 24/28, Victoria Street, London, S.W.1.

93 : 1951 B.A. Screw Threads
(3/- post free).

778 : 1951 Steel Pipes and Flanged Joints for Hydraulic Purposes
(4/- post free).

1685 : 1951 Bevel Protractors (Mechanical & Optical)
(2/- post free).

HAZLETON MEMORIAL LIBRARY

The following publications have recently been received and are available to members. It would be helpful if the volume classification number could be quoted when borrowing books.

REVIEW "Technical Reference Book of Compressed Air Terms and Standards" published by the British Compressed Air Society. (Price 10s. 6d.)

There have been two previous editions of this work by the Society, and this, the third edition, has been expanded to include additional British Standards Specifications and to cover a wider field.

Apart from terms of standards, the book is of considerable technical value.

Parts I and II deal, in sections, with various types of compressors and their selection, installation and maintenance.

Part III covers test codes, measurement of air flow and methods of calculation.

Parts IV and V deal with Rock Drills and Pneumatic Tools which are fully discussed, and, in addition to illustrations, there are many graphs and tables.

A great amount of valuable data and information has been collated to make this book appear almost indispensable to the compressed air technician.

ABSTRACTS

621.9 MACHINE TOOLS

"Production Engineering" (Vol. I—Machine Tools) by R. Dent. *English Universities Press, Ltd., London. 366 pages.*

This volume in the Technical College Series is based primarily on the requirements of the Higher National Certificate in Production Engineering, and thus embraces material required for other examinations in the subject. The ten chapters cover Planning: Speeds and Feeds; Capstan and Turret Lathes; Planing, Shaping, Slotting, Boring and Drilling Machines; Gear Cutting; Jig Boring Machines; and finally, Machine Tool Design with typical calculations. Each chapter contains illustrations and gives a set of exercises for which answers are provided, and the whole is backed by an index, short bibliography, and the following tables: Four-figure Logarithms; Trigonometrical Functions (Sine, Cosine, and Tangent to one minute); Cutting Speed—R.P.M.; Brinell Hardness Numbers; Decimal Equivalents of Fractions; English-Metric Conversion.

331. INDUSTRY AND SOCIETY

"Industrial Sociology" by Delbert C. Miller and William H. Form. *Harper & Brothers, New York. 880 pages.*

This book has as its theme the mutual interdependence of personal satisfaction and efficient production. In the first of the five parts into which the book is divided the authors, outlining the background, have reviewed the work of Elton Mayo and drawn freely on the findings of the Hawthorne Investigations, as well as lesser-known research work. The second part is a survey of the organisation of American industry and the social structures both within and without the "Work Plant." Part Three deals with problems of worker placement, and, in addition to interviews and the usual psychological tests, lays stress on the importance of sociometric tests in establishing the worker's suitability for membership of a particular work group. The progressive social development of the worker through the home, school and work environment is dealt with in Part Four, while Part Five deals with the impact of industry on the community and society, with special reference to the increasing size of organisations and the diminishing influence of the individual other than as a member of a corporate body.

621.3 ELECTRICAL ENGINEERING

"Electricity as an Aid to Productivity." *The Institution of Electrical Engineers, Report of Conference, November, 1950. 52 pages.*

This is a record of the proceedings of a Conference organised by the Institution of Electrical Engineers to inform industry of some recent developments in factory electrification and the effect upon production. A series of lectures and discussions are reported under the following headings: Motive Power in the Factory; Industrial Heating Processes; Welding Applications; Handling and Inspection of Materials; Lighting, Heating, Ventilation, etc. The lectures were based on practical experience in a number of industries, and examples are quoted of the contribution which electricity has made and could make throughout all industry. Emphasis is placed on the use of electrical apparatus to increase production rather than on its technical design. In a number of instances, comparison of savings is made and the problems associated with electrification defined with a view to

determining relative productivity. Photographs and diagrams show typical examples of apparatus referred to, and the discussions and lecturers' replies are reported fully. The series is introduced and summarised in addresses.

621.7 WORKSHOP TECHNOLOGY

"Workshop Technology—Part III" by Dr. W. A. J. Chapman. *Edward Arnold & Co., London. 468 pages.*

This is the last Volume in the series designed to cover the work in National Certificate and City and Guilds of London Institute Courses. Part Three extends and adds to the material covered in previous parts, and relates to the Higher and Final Stages. Beginning with a chapter on Materials, Testing, Further Treatment and Properties, consideration is given to the processes of production in engineering. Other chapters are devoted to further consideration of the Lathe and Milling machine, and to Capstan and Turret Lathes. Other machine tool processes are either grouped under the heading "Miscellaneous" or given separate treatment, as in Screw Thread Production and Measurement, and Spur Gears and their Production. A survey of the Metal Cutting process includes a section on Surface Finish, and Measurement and Inspection relate both to Standards and to equipment used in the inspection of the product. The Installation and Maintenance of Equipment outlines equipment used, and methods employed in the servicing of plant, including reclamation of worn parts and major overhauls. There are 442 diagrams and photographs chosen from a wide variety of sources to illustrate specific points. An Appendix contains specifications and charts, and the whole is indexed alphabetically in terms of the text.

OTHER ADDITIONS

621.793 METAL COOLING

Richards, Edward S. **"Chromium Plating : A Textbook."** (3rd Ed.) *Lond., Griffin.* 1950. *154 pages. Illustrated. Diagrams.*

010. BIBLIOGRAPHIES, CATALOGUES

Harries, Joan M. *ed.* **"Union List of Bibliographies."** A selection of four hundred bibliographies with locations in some Metropolitan and Greater London libraries. *Lond., Greater London Division of the Association of Assistant Librarians.* 1950. *53 pages.*

050. PERIODICALS

Abstracting Services Consultative Committee, London. **"List of Periodicals and Bulletins containing Abstracts published in Great Britain."** Prepared under the supervision of the Committee ; issued by the Royal Society. (2nd Ed.) *Lond., Camb. Univ. Press for Royal Society.* 1950. *79 pages.*

070. NEWSPAPERS

"Newspaper Press Directory and Advertisers' Guide, 1951." *Lond., Benn Bros. 602 pages.*

331.1 PERSONNEL MANAGEMENT

British Institute of Management, London. **"Working Together : An Introduction to Personnel Management."** *Lond., The Institute.* 1949. *24 pages.* (Personnel Management Series 2.)

Lawe, F. W. **"Staff Management,"** *Lond., Institute of Personnel Management.* 1950. *28 pages.*

Locke, H. W. **"Fundamentals of Personnel Management."** *Lond., Institute of Labour Management.* 1943. *18 pages.*

Roberts, R. Lloyd. **"The Human Problems of Management."** (Rev. Ed.) *Lond., Institute of Personnel Management.* 1950. *20 pages.*

Urwick, Lyndall. **"Personnel Management in Relation to Factory Organisation."** (Rev. Ed.) *Lond., Institute of Personnel Management* 1950. *27 pages.*

331.152. CO-OPERATIVE ADMINISTRATION ; JOINT CONSULTATION

Chelioti, G., and others. **"Financial Information and Joint Consultation."** *Lond., B.I.M.* 1949. *28 pages.* (Conference Series 10.)

Choate, J. S. **"Separating Judicial and Executive Functions."** *Lond., B.I.M.* 1950. *11 pages.*

Graves, H. C. H. **"Joint Consultation at all Levels in a Small Company—A Case History."** *Lond., B.I.M.* 1950. *26 pages.* (Winter Proceedings No. 10.).

338. ECONOMICS ; CREATION OF WEALTH

Goyder, George. **"The Future of Private Enterprise : A Study in Responsibility."** *Oxford, Blackwell.* 1951. *179 pages.*

347.7 COMMERCIAL LAW

Munkman, John H. **"Employer's Liability at Common Law."** *Lond., Butterworth.* 1950. *339 pages.*

517.2 CALCULUS

Kells, Lyman M. **"Calculus."** (2nd Ed.) *Lond., Allen & Unwin.* 1951. *508 pages. Frontis.*

533.5 VACUUM PHYSICS

Guthrie, A., and Wakerling, R. K., *eds.* **"Vacuum Equipment and Techniques."** *New York, McGraw-Hill.* 1949. *264 pages. Diagrams.*

553.8 DIAMONDS ; DIAMOND TOOLS

Industrial Diamond Information Bureau, London. **"Diamond Tool Industry in 1950."** *Lond., Industrial Distributors (Sales), Ltd.* 1951. *11 pages.*

607 RESEARCH

University of Birmingham. **"Joint Standing Committee for Research Annual Report 21, 1949-50."** *Birmingham, The University. 92 pages.*

620.1 TESTING MATERIALS

Northern Aluminium Company Limited, London. **"Mechanical Tests and Their Bearing on Working Properties."** (2nd Ed.) *Lond., The Company.* 1950. *36 pages. Illustrated. Diagrams.*

620.6 ENGINEERING SOCIETIES AND INSTITUTIONS

Junior Institution of Engineers, London. **"Journal and Record of Transactions. Vol. 60, 1949-50."** *Lond., Percival Marshall.* 1950. *380 pages. Illustrated. Diagrams.*

621. MECHANICAL ENGINEERING

Camm, F. J., *ed.* **"Newnes' Engineer's Reference Book."** (4th Ed.) *Lond., Newnes.* 1951. *1,727 pages. Illustrated. Diagrams.*

621.18 BOILERS

Drayton Regulator and Instrument Company Ltd., West Drayton, Middx. **"Some Notes on the Formation and Utilisation of Flash Steam."** *West Drayton, The Company.* 1951. *23 pages. Diagrams.*

621.3 ELECTRICAL ENGINEERING

Institution of Electrical Engineers, London. **"Report of the Conference on Electricity as an Aid to Productivity, Nov. 1950."** *Lond., The Institution.* 1951. *52 pages. Illustrated. Diagrams.*

Philpott, Stuart F. **"Fractional Horse Power Motors."** *Lond., Chapman & Hall.* 1951. *367 pages. Illustrated. Diagrams.*

Chapman, W. A. J. **"Workshop Technology, Part III."** *Lond., Arnold.* 1951. *468 pages. Illustrated. Diagrams.*

621.74 FOUNDRY WORK

Marek, Clarence T. **"Fundamentals in the Production and Design of Castings."** *New York, Wiley : Lond., Chapman & Hall.* 1950. *383 pages. Illustrated. Diagrams.*

621.77 ROLLING MILLS

Northern Aluminium Company Limited, London. **"Continuous Strip Mill at Rogerstone."** *Lond., The Company, [n.d.]. 14 pages. Illustrated. Flowsheet.*

621.775 POWDER METALLURGY

Goetzel, Claus G. **"Treatise on Powder Metallurgy. Vol. II—Applied and Physical Powder Metallurgy."** *New York, Interscience Publishers.* 1950. *910 pages. Illustrated. Diagrams.*

THE LIBRARY Members are asked to note that until further notice the Library will not be open on Wednesday evenings or Saturday mornings, but will be open between 10 a.m. and 5.30 p.m. from Monday to Friday each week.

JOURNAL BINDERS Members are reminded that binding cases for the Journal are obtainable from Head Office, price 7/6 each post free. The cases, each of which will hold 12 issues of the Journal, are made of stiff board covered with imitation leather cloth, with gilt lettering on the spine.

CHANGE OF ADDRESS It would be of great assistance to Head Office if members would ensure that the business addresses contained in their records were up-to-date, and would notify Head Office as soon as possible of any change of appointment.

RESEARCH PUBLICATIONS A number of copies of the following Research publications are still available to members, at the prices stated :

Report on Surface Finish, by Dr. G. Schlesinger	15/6
Machine Tool Research & Development	10/6
Practical Drilling Tests	21/-
Test Charts for Machine Tools, Parts 3 and 4	5/6 each

These publications may be obtained from the Production Engineering Research Association, "Staveley Lodge", Melton Mowbray, Leics.

ISSUE OF JOURNAL Owing to the fact that output has to be adjusted to meet requirements, and in order to avoid carrying heavy stocks, it has been decided that the Journal will only be issued to new Members from the date they join the Institution.

IMPORTANT In order that the Journal may be despatched on time, it is essential that copy should reach the Head Office of the Institution not later than 40 days prior to the date of issue, which is the first of each month.

THE MANUFACTURE OF BALL AND ROLLER BEARINGS

by R. K. ALLAN,* A.M.I.Mech.E., M.I.Prod.E.

Presented to the Sheffield Section of the Institution, 13th February, 1950.

SINCE the beginning of the Rolling Bearing industry some 50 years ago, engineers in general and Production Engineers in particular, have shown a very marked interest in the methods of production of complete bearings and their components. Without doubt the greatest interest has been centred on the manufacture of steel balls, possibly because of the great quantities produced and the close limits to which these are made both as to size and sphericity, but perhaps also owing to the brilliant glittering effect of a quantity of them when nicely displayed on a background of black velvet.

Whatever the reasons for the interest and the implied belief that bearing engineers have command of some mysterious formulae and processes not at the disposal of others, it is as well to point out that the technique of production has been a matter of gradual development over the years to achieve the present-day state of perfection.

While it is true that cautionary measures may have to be observed about some new development or other, there is no impenetrable iron curtain shutting off knowledge of bearing manufacture from the outer world.

It is not possible within the confines of a short talk to present a detailed account of each and every step in production, but it is hoped that the broad survey to be given will be found more illuminating than a bare schedule of manufacturing operations.

It would be advantageous, first of all, to describe fully the different kinds of bearing and other accessories. Unfortunately time does not permit. Most of you, however, are already familiar with them and those who are not will find details in two previous papers by the author which appeared in the issues of the Institution Journal for January, 1947, and August, 1948.

STEEL The localised pressure at the contacts between rolling elements and rings is usually in the region of 200 tons per square inch, and since the stress at any one point occurs millions of times during the life of a bearing it is obvious that the fatigue resisting properties of the steel used is of primary importance.

* *Chief Draughtsman, Skefco Ball Bearing Co. Ltd., Luton.*

Preference is given to alloy steel with about 1 per cent. carbon and 1 per cent. to 1.50 per cent. chromium according to the size of the bearing. The chromium raises the elastic limit, induces a fine-grained structure and increases hardness penetration, hence the term " through hardened steel."

Both English and Swedish steels are used, the latter being produced from Swedish iron ore which has the advantage of low sulphur and phosphorus content.

From the concentration plant where the ore is crushed, ground in ball mills, and passed through magnetic separators, the concentrate passes on to be mixed with charcoal and coke fines, then placed in shallow sintering pans and covered with charcoal fines. In the sintering process the small particles are fused into larger ones and the sulphur content reduced to less than 0.01 per cent.

The sintered product then goes to blast furnaces, the fuel for which is wood charcoal, in which the ore is reduced and converted to pig-iron. The furnaces are tapped every four hours, the molten iron being poured into moulds to form pig-iron, or into ladles for transference to open-hearth furnaces.

Sixty per cent. molten iron and 40 per cent. selected steel scrap, previously melted in electric furnaces, are mixed in acid open-hearth furnaces in which the carbon content is reduced, and alloying elements added to provide the required analysis. When ready the furnace is tapped, the molten contents being carried by ladle and poured into moulds to obtain ingots of about 1¼ tons in weight.

This completes the steelmaker's work, and the ingots now go to the rolling mills to be formed into wire and rod for the manufacture of balls and rollers ; bar for small bearing rings ; tube for medium sized rings ; forgings for large rings ; and strip for the cages which space the balls or rollers in the bearing.

The ingot, about 13 in. square by 4½ ft. long, first goes to a reheating furnace, and when white hot is passed through the first stand of the blooming mill (Fig. 1) to form a bloom about 10 in. square by 7 ft. long. This bloom then passes to and fro through the second stand, and emerges as a length of red-hot steel about 5 in. square. It now passes to a hot saw where it is cut into billets about 6 ft. long.

The billets are pickled after cooling, and then surface defects are removed by swing-grinders, or cut out with a chisel. This work must be done thoroughly to avoid defects in the finished product. They are then re-heated prior to further rolling into bar, strip, wire or tube.

Billets for Bar first go to the merchant mill and to the finishing mill to bring them to size—1½ in. to 5 in. diameter. After finishing, the rolled bars are stacked on a cooling bed, and subsequently cut to length.

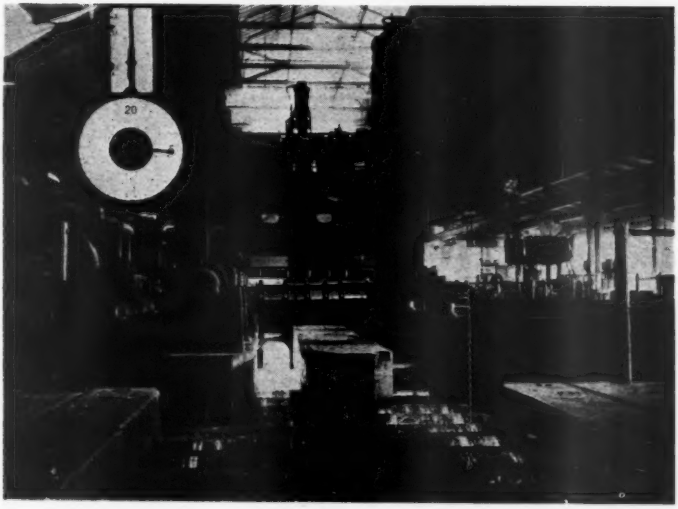

FIG. 1

Billets for strip go to the roughing mills, then through intermediate rolls, and finally to a series of three 4-high finishing mills. When cold, the strip to be used for bearing cages is cold-rolled to the required thickness.

Billets for wire are first formed into bar, which then goes to the wire mill where it passes between continuous pairs of rolls until it has the required diameter. When the wire leaves the last pair of rolls it is reeled on a coiler, and at this stage the wire may be moving at a speed of 55 to 60 ft. per second—about 40 m.p.h. After this the coils of wire are annealed and then go to the wire-drawing department for cold-drawing to size.

In the production of tube, a short billet about 8 in. diameter by 12 to 18 in. long is first pierced in a vertical piercing press to about three-quarters of the billet length. While still hot the hollow billet is formed into tube on a push-bench, by means of a mandrel pushing it through a series of dies (Fig.2).

Rings for large bearings have to be forged, the billet being first flattened and formed into a disc by a pneumatic hammer. After this operation the disc is pierced and then rolled in a ring-rolling mill. Rings of about 2 tons in weight are forged in a hydraulic press.

FIG. 2

All these products of the steel mill are annealed in electric furnaces where the internal stresses set up in rolling or forging are removed, and the material hardness made uniform for easy machining.

As a matter of passing interest, it may be mentioned that it takes about 6 tons of the various materials to produce 1 ton of ball bearing steel.

RAW MATERIAL INSPECTION

Even when the steel is the specially controlled product of the steel works, further examination and additional routine analysis and checks are made at the factory to ensure perfection as far as is practicable. Samples of bars and tubes for ring manufacture, and also wire and rod for balls and rollers, from each cast, are submitted for examination prior to bulk delivery. This inspection includes :

(*a*) Chemical analysis of the composition of the steel.

(*b*) Micro-examination in the annealed state for spheroidisation and decarburisation.

(*c*) Tests for hardness and machinability.

(*d*) Micro-examination in the hardened condition for carbide segregation, slag inclusions and general hardenability.

(*e*) Samples are fractured to permit examination of the fractured surfaces.

(*f*) The Cathode-ray Oscilloscope is sometimes used for sorting out material for hardness and the separation of mild steel from carbon steel.

Mild, medium carbon and spring steels, and cast-iron for bearing housings are subjected to a 10 per cent. check for various features.

Material for cages, rivets, spring rings and other bearing component parts are subjected to chemical analysis, general micro-examination for seams and inclusions, and for hardness, ductility, etc.

In addition to chemical analysis, non-ferrous material for cage manufacture is micro-examined for grain size, correctness of structure, and for hardness and machinability.

The felt used for sealing some types of bearings and bearing housings is tested for tensile strength and elongation, for its oil-absorbing and sealing qualities, and to ensure that it is acid-free.

TURNING

Bars and tubes from Raw Stores are first of all straightened and then have the surface skin removed, or " peeled," in centre lathes, or in Bigwood Centreless machines. The bars and tubes are then returned to store for subsequent issue to the Automatic Shop for the first stage in the formation of bearing rings.

On the automatics, which are 4-spindle and 6-spindle Gridley and B.S.A. Types, both inner and outer rings are simultaneously made from bar, the normal sequence of operations being :

(1) Drill inner and rough form O.D. of outer rings.

(2) Rough bore and trepan.

(3) Ream bore and part off outer ring.

(4) Finish form inner ring.

(5) Part off inner ring.

For larger bearings, the inner rings are formed from bar or tube in single-spindle autos and outer rings from tube in special single-spindle autos. A close-up view of one of these single-spindle autos is shown in Fig. 3.

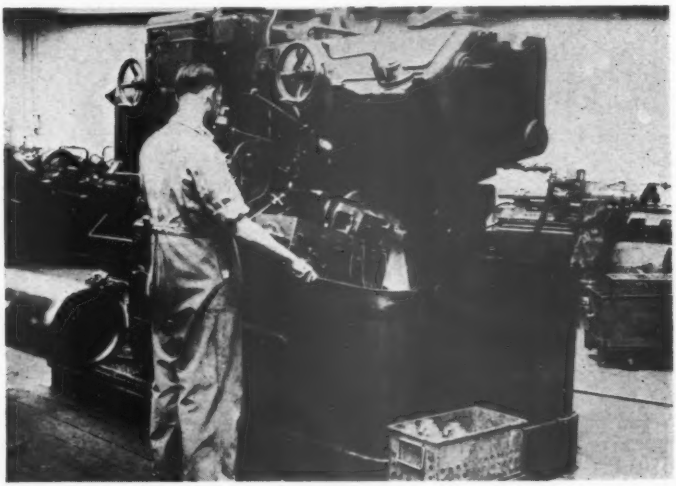

FIG. 3

The roughly formed rings now go to the Capstan Department where they are further machined in the bore, width and tracks. Circular form-tools are used for the grooves and recesses as they have long life and can be reground and set up without much waste of time. After turning, the rings are inspected all over to ensure that grinding allowances are correct. In this department thrust bearing washers, rollers, cages, and other items are also machined.

On turret lathes much the same operations are performed as on the automatics and capstans but for larger and heavier rings from sawn tube and forgings. Adaptor and withdrawal sleeves made from mild steel, used in conjunction with bearings having a taper bore, are also finish-machined in the turrets ready for grinding.

During all the above operations, continual dimensional checks with suitable gauges are made to ensure a quick pick-up of any errors.

HARDENING In the hardening shop the components are treated in various ways according to size and purpose. Small- and medium-sized parts pass through automatically fed roller or shaker-hearth gas-fired furnaces and reach a temperature of 850° C. before quenching in oil. After washing, they are tempered for one hour in an air stream at 150° C. in electric furnaces. The larger rings cannot be accommodated in the automatic furnaces, and have to be dealt with individually. Furnace temperatures are closely controlled and continuously recorded, both hardening and tempering being under laboratory control. The final hardness is 62 to 65 Rockwell, C Scale (approximately 660 Brinell).

After tempering, scale is removed by shot-blasting, and following magnetic hardness tests the components are ready for grinding, but samples from the batches are first checked for hardness, and fractured to permit examination of the structure of the hardened material.

GRINDING We now come to the most important series of machining operations—that of grinding. Grinding wheel speeds are about 6,000 ft./min. for vitrified wheels, and 7,500 ft./min. for rubber and bakelite bonded wheels, which agrees with usual practice.

Ring Widths. Rings are first ground to width on modern automatic surface grinders—chiefly of the Blanchard type. The rings are fed on to a revolving magnetic chuck and pass under the grinding wheel, which, by means of an electrical device operating the feed wheel, is automatically adjusted for wear. When one side is ground, the rings are demagnetised, washed and then ground on the second side, after which they are conveyed to the inspection table.

Another type of machine grinds both sides simultaneously, the rings from a hopper being fed between two large grinding discs.

External Diameter. Centreless grinding is now the principal method of grinding outside diameters, the results obtained being generally equal to mandrel grinding. Avoidance of lobes is best achieved in the first passes by setting the work somewhat higher

between the grinding and control wheel centres than usually recommended. Chatter marks may result, but are removed on the final pass through with the work at normal height.

Bore Grinding. For grinding bores between about 1 in. and 4 in. Heald Gaugematics are employed. Several rings are ground at one time—the number varying according to ring width—and are secured in holders about 5 in. long which are hydraulically clamped to the machine spindle. When the bore is nearly to size the first control plug enters, which causes the wheel to be automatically dressed, and when the size is correct, a second control plug is allowed to enter the bore, this action causing the feed to throw out. A guard comes down over the grinding wheel and the spindle stops rotating to permit the holder to be removed and another inserted.

Grinding machines for bores up to about 1 in. are similar in principle. Fig. 4 is a close-up of the headstock with a holder in position.

FIG. 4

Track Grinding. Where the shape of the track for the rolling elements permits, preference is usually given to generating the form by making either the work-head or the grinding wheel head oscillate, thus generating the correct track contour. With this method the grinding wheel keeps its shape and no dressing, apart from the initial rough forming, is necessary.

Generally, for the smaller ring sizes the grinding wheel oscillates, whereas the work oscillates in the case of the larger sizes.

Where contours cannot readily be produced by the generating method, form grinding must be used. Obviously, in order to ensure correct shape, repeated truing of the grinding wheel cutting face is essential, and this is done automatically each time a ring is ground by means of a diamond-truing device. For grinding the tracks in taper roller-bearing inner rings the grinding wheel has a very slight side movement, and the rings are either draw-clamped onto a spigot on the spindle, or held by an expanding chuck.

During all grinding operations samples are taken continuously for inspection of dimensions, for laboratory checks which include etching for grinding burns, and for Magna-flux tests for cracks. The apparatus for checking dimensions is simple but efficient and designed for each specific operation. Errors are read on minimeters or dial gauges.

Measurement is comparative throughout, standard test pieces being used to set the apparatus. The test pieces are in turn periodically checked against Johansson standards, using such instruments as the Zeiss Optimeter or the Prestwich Fluid Gauge to control the comparative measurements.

Polishing. Where the track forms are finished by generating, a final polishing operation is introduced, using hardened steel or carbide pads with special impregnated tape, to produce a scratchless surface finish. After this operation there is 100 per cent. inspection for size, and ocular inspection under powerful lamps to ensure freedom from grinding marks or other defects likely to impair bearing life.

STEEL BALLS AND ROLLERS

We now come to the component which, as previously mentioned, incites so much curiosity about the methods of manufacture. While the principles involved in present methods have changed but little since the time when lathe turning of balls was abandoned, there have been changes in machines and production technique from time to time giving improvement in quality and output.

Steel balls up to 1 in. diameter are cold pressed from chrome steel wire or rod in automatic presses of the type shown in Fig. 5. The wire is cut to length as it passes through the machine, and pressed between two spherical dies which come together and thus form a rough sphere with a slight flash or burr around an equator of the ball.

Fig. 6 shows the business part of the machine with the blank about to be cut to length.

The flash is then removed in rotary filing machines of the special design seen in Fig. 7, the balls continuously passing between rotating steel filing discs until no flash remains, and the balls are to a given size.

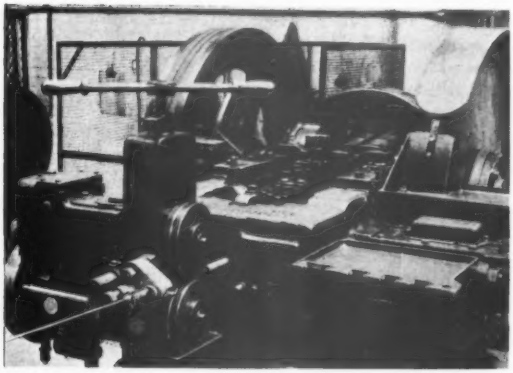

FIG. 5

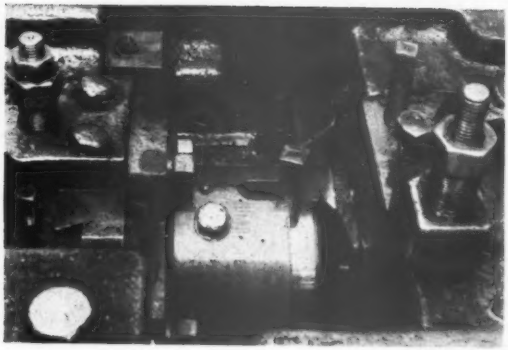

FIG. 6

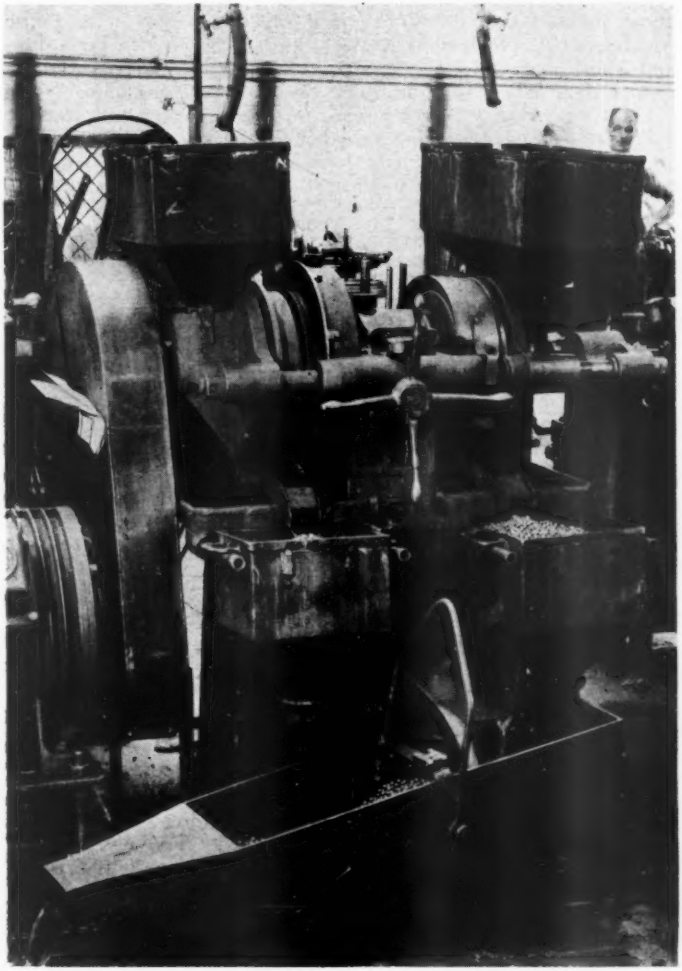

FIG. 7

In machines of the type shown in Fig. 8, the unhardened balls are then precision ground to within a few thousandths of an inch above finished size, the balls travelling around grooves in a disc which holds them against a rotating grinding wheel. Both discs and wheel operate so as to make the balls rotate and continuously change their axis of rotation, thus obtaining true sphericity.

Hardening in a conveyor furnace on the shaker-hearth principle follows the above operation, and when the balls or rollers reach the far end of the hearth they drop through a chute into the quenching medium, oil being used for small sizes, and brine for the larger sizes.

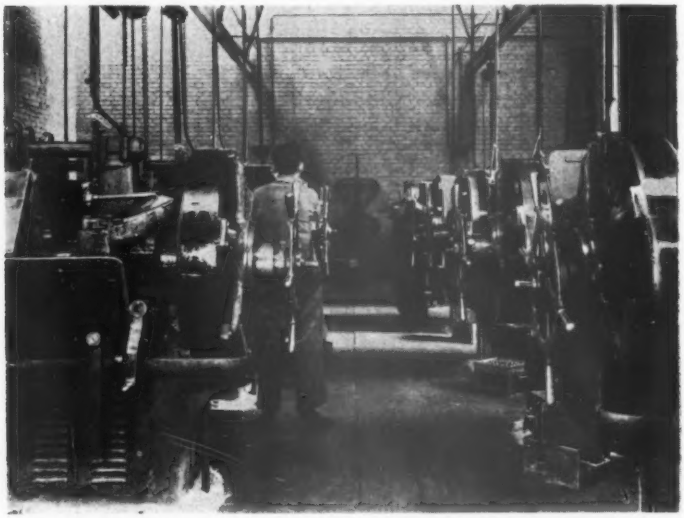

FIG. 8

Precision grinding to size follows hardening, in machines somewhat similar to those already described. Fig. 9 shows the mixing devices used to ensure that all balls are ground equally and uniformly. Each time they pass round the grooves in the pressure plate they are picked off and pass along these trays, and thus most likely enter a different disc groove each time. This grinding operation takes several hours, since the material is removed very slowly.

Polishing is achieved by tumbling in lime, and then burnishing with leather scraps in revolving drums.

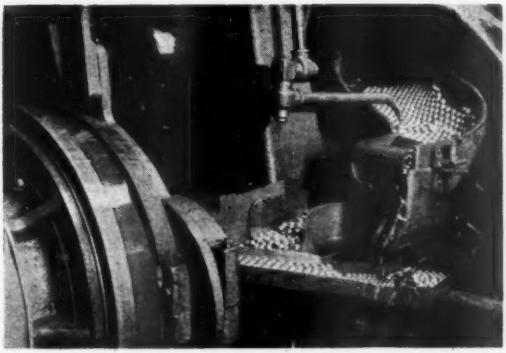

FIG. 9

After each operation there is a sampling inspection for size and sphericity, and finally ocular inspection in which the balls are rotated to bring all parts of their surface under scrutiny.

As the balls are manufactured in millions, it is obviously impossible to measure each one by ordinary means, and considerable ingenuity has been expended in this direction.

Fig. 10 shows one type of machine in which the balls are graded for size in steps of 0.001 mm. (= .00004 in.), by passing from a hopper and rolling down a pair of knife-edges set slightly out of parallel. They drop through at the appropriate points into tubes which convey them to the grading drawers beneath.

Fig. 11 is a view of part of the roller sorting room.

There are three types of rollers, namely cylindrical, taper and spherical. Cylindrical rollers are cut from rod or wire ; taper rollers are cold or hot-pressed to shape in much the same way as for balls ; whilst the spherical rollers are formed from rod in automatics. Heat-treatment and inspection are by similar methods to those already described for balls, but with modification to suit the shape of the rollers.

The diameter of cylindrical and taper rollers is ground in centreless machines. The ends of the cylindrical rollers are also ground square to the axis, whereas the taper rollers, which have the big-end sphered, have those ends ground in special machines which form-grind the correct curvature, the centre of which coincides with the apex of the roller cone.

The machines employed for grinding rollers with a spherical contour, provide another example where the form is generated by oscillating the work head. The rollers are held in the work head

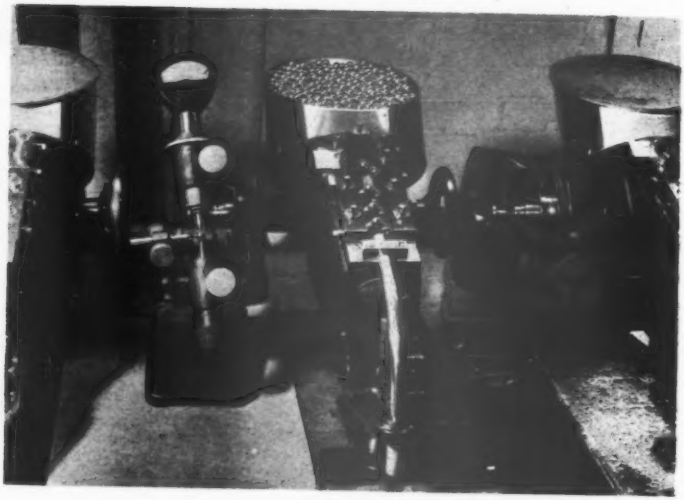

FIG. 10

FIG. 11

by a simple end-pressure chucking device. These rollers also have both ends sphered, one end convex and the other concave, this being done by form grinding the curvature with the rollers held on a spherical magnetic chuck.

CAGES A variety of cage types are used, depending on size, type of bearing, speed of the bearings and other functional characteristics.

Pressed steel or brass cages for single row ball bearings are produced in four straightforward operations, namely :

(1) Blanking and piercing ;

(2) Crimping ;

(3) Forming, and

(4) Piercing rivet holes.

After tumbling to remove burrs they are ready for assembly. For self-aligning bearings, pressed cages require very intricate press tools.

Drilled bronze or steel cages are generally produced in automatic lathes from turned blanks. Pockets for the balls or roller are drilled and reamered in simple jigs with spacing attachments to obtain the correct pitch. Multiple drilling is not impossible, but is seldom economical.

ASSEMBLY After thorough washing, the inner and outer rings are sized up in pairs for track diameter to give the required internal slackness, and the balls inserted. The exact number of balls required are released from a hopper by pushing the rings against a lever. The cage halves are then placed in position, and automatic machines assemble the rivets, which are then closed over in a power press.

When bronze cages are fitted, the rivet heads are formed by spot welding.

For taper roller bearings with pressed steel cages, the rollers are placed in the cage pockets and the inner ring then sprung into position.

FINAL INSPECTION After assembly, the bearings are thoroughly washed in a hot anti-corrosive solution which is pumped through a jet into each bearing. When dry, they are inspected for correctness of external dimensions and assembled internal slackness, etc. From the inspection benches they pass to the washing room for a second washing, this time on rotating spindles immersed in the washing solution. Each bearing is then put on a high speed spindle to test for smooth and silent running.

Bearings which are approved are then immersed for a short period in hot preservative grease, and, after cooling, are wrapped in grease-proof paper, placed in cartons, labelled, and sent to finished stores.

DISCUSSION

THE PRESIDENT (Sheffield Section) : I think you will agree with me that Mr. Allan has given us a most interesting and thorough paper on the manufacture of ball and roller bearings. It is of particular interest to Sheffield because he starts with steel melting and then goes on to rolling and forging and very fine machining.

I would like to ask Mr. Allan in what batches the various sizes of bearing are put through. What are the minimum and maximum sizes ? Also, can he tell me when ball bearing manufacture first commenced, and when and where was the first ball bearing used ?

MR. ALLAN : I cannot hope to answer every question which may be asked tonight, as I do not claim to be an expert on every aspect of the subject.

Regarding your first question, rings and rollers for any particular size naturally follow a particular sequence of operations through the factory, and eventually the rings arrive in the ring stores where they are stored and graded for track diameter, and are re-issued in accordance with demand. The steel balls and rollers follow the same kind of procedure and are re-issued to marry up with the rings. Certain sizes and types of bearing are required in very large quantities and others in small quantities, which follow the same route, avoiding ' bottlenecks.' Production is, of course, adjusted to the demand.

Modern bearing manufacture did not commence until about the beginning of this century. It was in 1898 that the first scientific investigations into the characteristics of bearings was made by Professor Stribeck in Germany. About the same time Professor Goodman at Leeds University was carrying out a number of experiments. Those experiments covered load capacity and various details of construction. About 1890 there were varieties of the cup and cone bicycle bearing, similar in principle to the modern angular contact type.

In my book, " Rolling Bearings," the historical aspect is covered, and goes right back to the time of the Egyptians who were using rollers of a kind for moving large monuments. It is not possible to say exactly when the first radial bearing with true rolling motion was used, but the year 1794 is probably about right.

The smallest ball bearings made are 1.5 mm. outside diameter, and the largest about 7 ft.

MR. LEVESLEY : I was very interested to see in the film the illustration of a large bearing. Could you give us any information about the distortion which takes place in the hardening and what method is used, and how much is allowed for grinding after hardening. Also, what are the subsequent hardness readings around the ring ? Do you get any variation ? Another point about fairly large bearings in the order of, say, 26 in. is what is the limiting factor in their use in the case of heavy loads or great speed ?

MR. ALLAN : The amount of distortion is not very great. After hardening the grinding allowance is approximately $\frac{1}{64}$ in., but varies slightly with size and ring section.

As mentioned in the paper, the final hardness is 62 to 65 Rockwell, C scale. In individual rings the hardness is, to all intents and purposes, uniform.

The limiting speed is usually defined by an empirical formula. With single row ball bearings, 300,000 divided by the bore in millimetres gives the normal maximum. 500,000 divided by the bore gives the maximum for bearings with a solid type of cage and 750,000 divided by the bore gives the maximum for cages made of synthetic material. These are approximate figures for there are other factors such as lubrication, amount of cooling, etc., which affect the maximum speed. With a bearing of about 12 in. bore and having a solid cage the speed could be about 1,000 r.p.m. These factors of 300,000, 500,000, 750,000 have all been found from experience. There is no physical law that I know which would enable you to arrive at it in any other way.

Load capacity is related to the total number of revolutions made, and theoretically at least, not to the speed.

MR. PRYOR : I was interested in the passing note on etching tests for grinding burns. Do you know what sort of effect grinding burns are likely to lead to and do you know how the degree of seriousness is assessed ?

MR. ALLAN : I do not know the complete answer but the laboratory people realise the limitations of grinding burns, and all I say is that if there is a grinding burn of any depth, then it will affect the life of the bearing. The point where you get the burn is, of course, structurally weak. With the very high local stresses obtained, then at that point of weakness the material will break away and leave the surface pitted.

MR. PRYOR : It would be in the track ?

MR. ALLAN : Yes, or the rolling elements. In fact, there should be no grinding burns. The surface is the important part of the material. If that is faulty in any way due to grinding burns or any other defect, then the bearing will not give maximum life.

With the modern method of calculation 90 per cent. of all the bearings used will give a greater life than the estimated life ; 10 per

cent. of the bearings will probably not come to that life exactly. Therefore the average life is five times the estimated life. This method of assessing life is based on experience and enables the user to have a good idea of what he can expect.

A VISITOR : I have listened to your paper with interest and paid particular interest to the film. You appear to have stressed the quality of the steel being used, Swedish material apparently. During the war we had difficulties in getting Swedish ores and steels. I presume that since then you have had to use possibly Lowmoor. Have you found much difference in your scrap deficiencies ?

With regard to the particular steel, again the same analysis and the same type of steel appears to have been used for at least thirty years to my knowledge. Has anything been done with regard to a better quality of steel for the ball race, particularly those which come into contact with certain temperatures in modern machines ?

MR. ALLAN : Both English and Swedish steels are used. The differences are not so well-defined that I can give you a definite statement that there is more scrap with the one than with the other. The English steel we are getting today is very good indeed. Thirty years ago attempts were being made to find an English steel which would compare with the Swedish. In those early days nothing produced here was as good as the Swedish, or it was far too costly. The position is different today. During the war and since we have obtained satisfactory English steel.

Whether the life curve will show greater dispersion or not is uncertain as a sufficient number of tests have not been made. You cannot simply take a batch of bearings and test them against another batch ; thousands of bearings must be tested before coming to any definite conclusion, because there are so many variables.

There have been a number of attempts to improve the steel by the use of vanadium and molybdenum alloys. Their effect on bearing life is not too clear. For high temperature work I have heard of stellite being used, but it was so difficult to machine that it was quite impracticable from the commercial angle. For high temperatures the loads are usually such that you can even allow the bearings to run quite hot. All the fine workmanship which has gone into the bearing is, of course, lost. Bearings are used in kilns, for example, at quite high temperatures, and usually last sufficient time to warrant their adoption. Normal lubrication is usually impossible.

A VISITOR : I should be interested to know whether the material used for the balls, rollers and for the rings is absolutely identical. As we know, plain bearing conditions are different from those of

roller bearings and there you have to have considerable differences. Is there any difference at all between the composition of the material used for the balls and races ?

MR. ALLAN : There are very slight differences in the material, chiefly to do with size. The slight variation is usually in the amount of chromium, the smaller balls and rollers having less than the larger ones. The same applies to the rings. It is a question of hardness penetration.

MR. WIDDOWSON : Is the finish on the ring produced just from a grinding wheel ? What degree of concentricity on a bearing is it possible to make on a 2 in. bearing ? I think it is about three-tenths of a thou.

MR. ALLAN : The concentricity varies with size, of course, and with the ring section. You will understand that very thin section rings are relatively sensitive to distortion. Your figure is fairly close to the mark for an average bearing but may go up to about five-tenths for a bearing of 3 in. diameter. With regard to the finish on the tracks, if the form is generated there is a criss-cross effect due to the grinding wheel oscillation and it is in these cases that polishing is necessary. That is done by special steel pads or carbon pads with a suitable kind of impregnated tape. The track surface finish is about six micro inches for the average rolling bearing.

INDUCTION HARDENING AND BRAZING

by R. J. BROWN, F.I.M., A.M.I.Mech.E.

Presented to the Coventry Section of the Institution, 17th October, 1950.

THE vast amount of information published on the many applications of the high frequency method of heating in the United States during the past few years has stimulated considerable interest in this country, particularly as the information indicates that this method of heating has largely superseded the conventional methods in certain processes, a specific example being the skin hardening of ferrous articles. In actual fact, it is extremely difficult to say to what extent the high frequency induction process is used in the United States, but the wealth of information published has firmly established that considerable economy in both fuel and labour is possible.

Probably the main appeal of induction heat-treatment is that the processing equipment can be located immediately on the production line, making flow production possible without any interruption for batch treatment. The heating operation takes place on a precision machine, which is, in fact, a machine tool, and in many cases of skin hardening, the operation may be the final one, without the need for subsequent grinding or lapping.

It is fortunate that the many virtues extolled for the process have not caused conventional heating methods to be entirely replaced. It is a fact that the enthusiasm of some authors has been over rated, with the result that initial disappointments in its application in this country have been followed by a cautious approach to the many problems involved in the process.

The work of H. R. Barfield[1] dealt primarily with the theoretical aspect of the method. The present article is confined to the practical aspects of the process.

High frequency heating for the purpose of surface hardening first achieved world prominence as the result of the work of the Ohio Crankshaft Co. in developing the Tocco method of hardening crankshaft journals and pins, using a rotary alternator. A considerable extension in the application of induction heating methods

[1] H. R. Barfield, " Industrial High Frequency Heating," a paper presented at a meeting of the Coventry Section of the Institution of Production Engineers, 1949.

occurred during the war years 1940–45, in the United States, and this brought about the successful development of the industrial thermionic generator which is now being used quite extensively.

OPERATIONAL FREQUENCY OF EQUIPMENT

Induction heating is possible at quite low frequencies. Such heaters have only restricted uses; the high frequency type of heater operating at frequencies of from 1 kc. per sec. to 10 mcs. per sec., are of interest, although for induction heating a more useful range falls between 10 kcs. per sec. and 1 mc. per sec.

Dr. Barfield described the relationship between frequency and depth of penetration of the induced current. Generally speaking, it is the penetration above the Curie point which is of interest, as this is a measure of the minimum depth of skin which can be hardened. Frequency is not only related to depth of penetration, but also to the cross-section of the material which can be effectively processed. For a cylindrical workpiece, the minimum radius which can be successfully heated is approximately three times the depth of flux penetration. This explains the unsuitability of the rotary alternator when used for the surface hardening of components of small cross-section.

GENERATORS

Three types of generator are available: (1) The rotary alternator, for frequencies up to 10 kcs. per sec.; (2) spark gap or (3) thermionic oscillators which, at frequencies of 100 kcs. per sec. up to about 1 mc. per sec. are used for the heating of metals. Of these, the rotary alternator and the thermionic oscillator are the most usual, but both are subject to certain limitations although they can be regarded as complementary to one another.

The choice of generator depends upon the type of application involved. For deep hardening or through hardening, the rotary alternator is likely to be the most efficient, owing to the greater depth of current penetration which enables a greater heat input to be achieved at high power without the occurrence of surface fusion. For shallow hardening and for heating of materials or parts of thin section, the higher frequency thermionic generator must be employed.

A disadvantage of the higher frequencies developed by the thermionic oscillators is that it is not easy to conduct the current for any appreciable distance without serious losses. The lower frequencies developed by the rotary generator can be quite conveniently conducted over considerable distances. Co-axial feeders which show a reasonably small power loss are, however, now available. The efficiency of rotary generators is claimed to be in the region 60 to 90 per cent., whereas the efficiency of the thermionic oscillator

is generally little over 50 per cent. As the applicator is often the primary cause of losses, with good design the net result may favour the thermionic generator.

HARDENING BY HIGH FREQUENCY INDUCTION HEATING

The most attractive application of the process is probably the skin hardening of shaft- or pin-like components of cylindrical section. Typical examples in the motor industry are gudgeon pins, selector rods, and rocker shafts. This type of component can be hardened very efficiently at high speed in the production line. Using a 20 kW. generator operating at a frequency of 450 kcs. per sec., it is possible to harden such parts at a throughput rate of about 5 ft. per min. with an input to the inductor of 10–15 kW. giving a power density of 15 to 25 kW. per sq. in. Selector rods can be hardened (see Fig. 1) at a throughput speed of 6 ft. per min. with an inductor

FIG. 1

load of 10 kW. giving a power density of 20 kW. per sq. in. In the surface hardening of engine valves made in Silchrome No. 1 steel, shown in Fig. 2, a hard surface is essential owing to side thrust under operating conditions. The valves are spun and hardened by the progressive method, the hardening temperature being

between 1,000 and 1,050° C., a hardness of 55 Rockwell "C" being obtained. No other method of hardening would be feasible for this type of component.

Much work and thought has been devoted to the possibilities of gear hardening. True contour hardening of gears is an extremely difficult operation, but if virtual through hardening of the teeth can be tolerated, the operation becomes quite straightforward. True contour hardening is a matter of considerable precision, and necessitates pre-heating the gear in order to reduce the thermal gradient between the surface and the core of the gear teeth. This

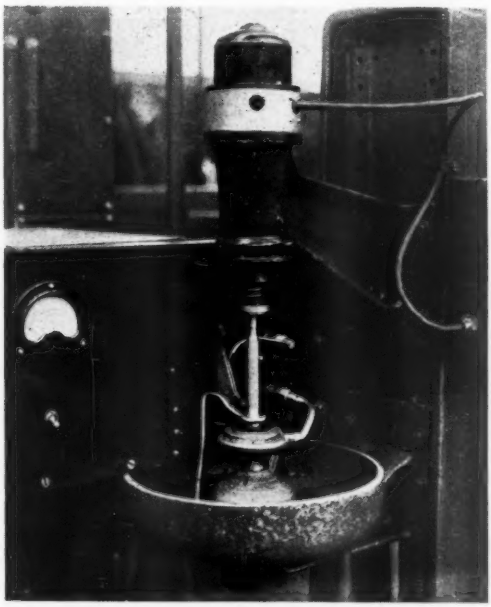

FIG. 2

method was evolved some years ago, and it was found possible to contour-harden gears down to 14 pitch under laboratory conditions, Since this early experimental work, American workers have followed a similar line of thought, and are now employing a pre-heat for gear hardening, but evidence is still lacking as to their success

in achieving true contour hardening. An interesting development in America is the true contour hardening, involving induction heating of carburised gears.

Local heating for hardening or tempering is an ideal application. Compared with alternative methods, the thermal efficiency is excellent and the speed of heating ensures a low labour charge. By the design of suitable handling equipment employing conveyor mechanism and interlocking switches, the process can be made fully automatic. Such a machine for hardening starter rings, has been built recently in this country. Fig. 3 shows the machine with a starter ring in position.

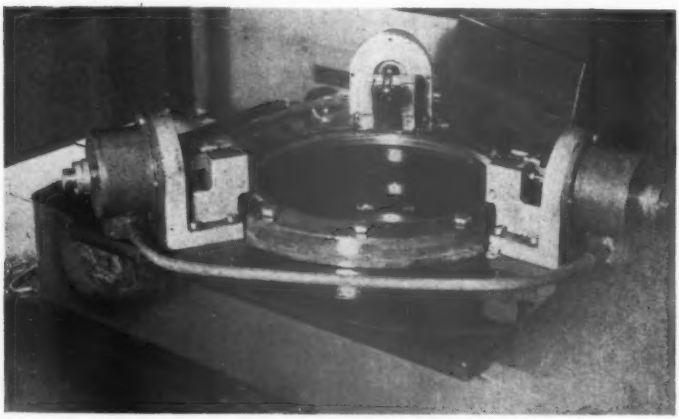

FIG. 3

High frequency methods of heating for brazing and soldering are finding increasing application. Brazing of a phosphor-bronze pad to a cast-iron impellor is successfully accomplished using a special grade of silver solder, and there are many components, such as the change-speed levers shown in Fig. 4, which are regularly brazed using silver solder. The main reason for using silver solder, which is costly compared with ordinary brazing solder, is that the melting point is very much lower than that of brazing solder. This is a considerable advantage where the degree of scaling during heating must be minimised, and where the effect of heating upon the mechanical properties of the part must be localised. Probably the greatest use of induction brazing is made in the manufacture of tipped tools.

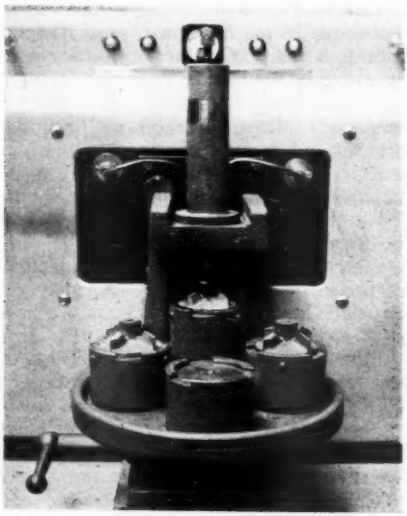

FIG. 4

STEEL FOR SKIN HARDENING

The choice of steel to be subjected to skin hardening naturally depends on the use to which the finished part is to be put. In the majority of cases, skin hardening is applied to plain carbon steel containing between 0.30 and 0.60 per cent. of carbon, the actual carbon range used depending upon the hardness required and the mass and shape of the component. For cylindrical parts which have a relatively simple stress pattern in the hardened zone, a carbon content of 0.45 to 0.50 per cent. is necessary if a surface hardness in excess of 62 Rockwell " C " is to be achieved. For starter rings locally hardened on their clash faces, a considerably lower carbon content will develop a similar hardness owing to the small mass of the teeth and, in order to avoid trouble resulting from the complex stress system in the hardened zone, the carbon range is of the order of 0.32 to 0.38 per cent.

Highly stressed parts are normally produced from alloy steel, but the possibilities of substituting a surface-hardened carbon steel for through-hardened alloy steel components are surprisingly large. This is obvious when it is considered that a notable percentage of highly stressed working parts subjected to bending and torsional stresses, such as rear axle shafts, do not need to be through hardened.

The condition of the material prior to surface hardening may be as-rolled or normalised, or hardened and tempered. For the maximum economic benefits of induction hardening, obviously the hot rolled or normalised condition is the most attractive, but in order to achieve maximum hardness in the short heating times involved in the process, the grain size must be quite small. This condition is necessitated by the distance over which the carbon atoms have to disperse in order to obtain uniformity of solution at the time of quenching. For example, 0.38 per cent. carbon steel in the hardened and tempered condition would develop a surface hardness on induction heating, of 62 Rockwell " C " in both the hardened-and-tempered and in the fine-grained normalised conditions, whereas in the coarse-grained annealed or over-heated conditions, the surface hardness under similar processing conditions will not exceed 58 Rockwell " C."

A practical difficulty in the surface hardening of components made from bar stock is the normal decarburisation of the material as produced. The depth of the decarburised layer varies from practically nothing to 0.025 in. or thereabouts. Up to the present time no steel producer appears to have been interested in producing steel which is either free from decarburisation or re-carburised. It is thus necessary to turn or grind 0.030 in. of material from the bar surface to ensure freedom from this undesirable condition, which would seriously impair the final hardness of the component. At the present time, the price of bar stock suitably ground or turned to ensure freedom from decarburisation, is quoted at approximately twice the usual price for bright drawn stock.

This astounding difference in cost reduces the effect of the economies which can be made by employing high-frequency heating. It is in fact much cheaper to buy hot-rolled bar stock, and either cut to size or cut to convenient lengths and centreless grind as a normal production operation.

BRAZING MATERIALS

Most of the commercial brazing materials can be used successfully in conjunction with induction heating. Silver solder is the most convenient if not the most economical, owing to the fact that its melting point is low, it flows extremely well, and its low melting point enables the zone of heating to be extremely localised. At the same time the relatively low temperature reduces the amount of scale formation. For silver solders, the usual fluxes may be used, although for certain applications "killed spirit" works quite successfully, and has the advantage that it is more easily removed than the glass-like slags produced by using the borate type of flux.

The normal brazing spelters can also be used and copper brazing is being carried out successfully in inert atmospheres. Copper

brazing by this method of heating is, however, much less convenient than the extensively used continuous brazing method employing a conveyor-fed furnace.

TRANSFORMER AND INDUCTOR REQUIREMENTS

One of the greatest difficulties encountered in the induction heating of components other than simple cylindrical objects, is to induce a magnetic field of the desired form without undue losses. This can only be achieved by correct design of the transformer, sometimes called the concentrator, and the inductor which form part of the heating unit. Several types of transformer have been used and until recently that most extensively employed (see Fig. 5), consisted of a multi-turn

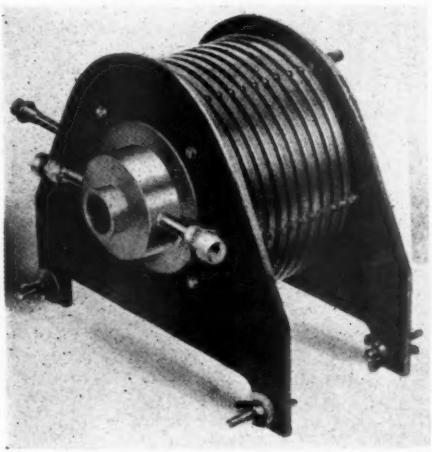

FIG. 5

primary surrounding the single-turn secondary, having the inductor let in the end. This type of transformer is far from efficient, the secondary current distribution being extremely poor and resulting in losses of the order of 40–50 per cent. The auto transformer, shown in Fig. 6, is another type that has been used experimentally, but the efficiency drops to a very low figure when feeding loads at high power density, owing to the inability of the secondary turn to deal with very heavy currents. The auto-transformer also has numerous practical limitations.

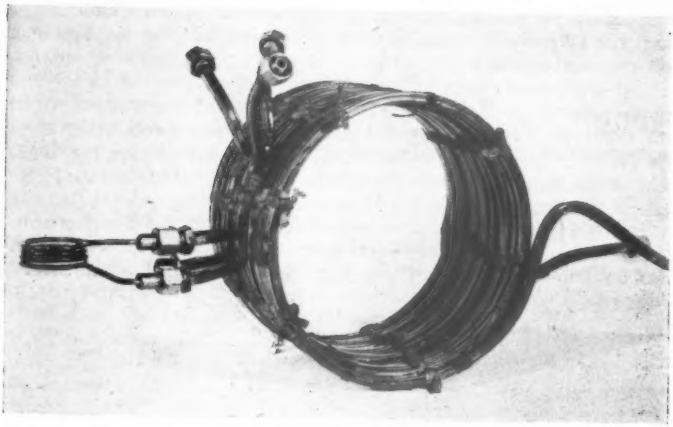

FIG. 6

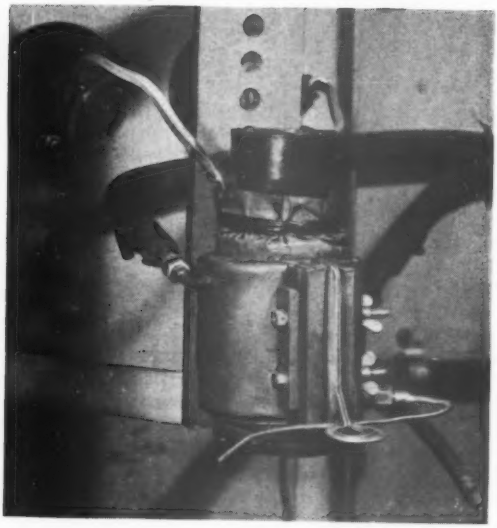

FIG. 7

The torroid transformer (see Fig. 7), which appears to have possibilities for producing very large currents, is of considerable interest. The most successful design is that employing an internal primary winding within a single turn secondary, with extremely close coupling. The loss in such transformers can be as low as 20 per cent., this being a considerable improvement over the previous types of transformers. There is little doubt that even more efficient designs of transformers are possible provided their manufacture and application are a practical proposition.

The object of a transformer between the generator and the inductor is to step down the voltage and increase the current. This permits the use of a single-turn inductor at a low voltage instead of the old type of multi-turn coil (shown in Fig. 8), which is used at

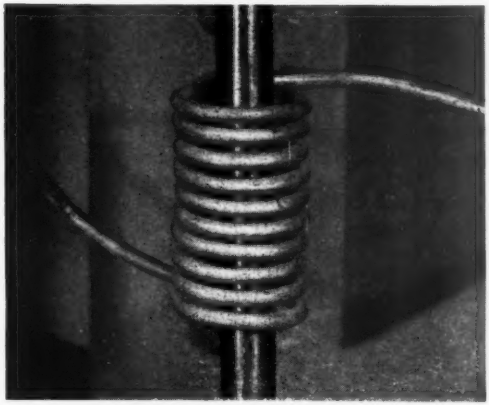

FIG. 8

high voltage. Although the electrical losses with multi-turn coils are usually lower than for the equivalent single-turn heavy-current type, it often happens that the increased thermal efficiency made possible by the use of a compact single-turn inductor, more than compensates for its lower electrical efficiency. Quite apart from this net saving of power, the greatly reduced voltage is of considerable practical assistance. High flux densities are impossible with the multi-turn inductor but the single-turn inductor enables the field to be extremely localised, thus giving the high flux densities where necessary for successful skin hardening.

Reference has been made at times to the so-called " gap effect," this being a low-temperature zone immediately opposite the gap in the inductor, which is due to the high frequency energy flowing along the path of least impedance. The effect is generally overcome by spinning the work within the inductor. By the incorporation of suitable feed plates in the design of the inductor, so ensuring that the current is fed to the inside edges of the gap, this effect can be largely overcome.

Probably one of the most difficult applications of high frequency heating is the hardening of bores. Such an application requires an extremely carefully designed inductor, because the high-frequency current has to be made to follow the outside diameter of the inductor, whereas it would normally follow the shorter path along the internal diameter.

POWER REQUIREMENTS

The minimum power requirements for through heating are determined by the surface radiation loss of the component. For raising steel to the hardening temperature range (800–900° C.), the mean power delivery to the centre surface must exceed 60 W. per sq. in. In induction heating, owing to the local nature of power delivery, four to five times this value is usually required. For the starter ring shown in Fig. 3, the temperature reaches equilibrium at 810° C. with a mean power delivery of approximately 200 W. per sq. in., with 10 kW. fed to the inductor.

The upper limit for through hardening is dependent on cross-section as well as surface area, and small diameter bar or strip can be uniformly through-heated at high speed, using power densities as high as 7 to 10 kW. per sq. in., without excessive surface temperature. In this case, little power is lost in radiation and the power requirement is related almost directly to the volume of the load and is only slightly in excess of the theoretical minimum value of 70 kW. per cu. in. per sec. For brazing operations, conditions are very similar, although 20–25 per cent. less power is required.

The minimum power requirement for surface hardening is obtained when a pre-heating operation is used, and under such conditions power densities as low as 2 kW. per sq. in. are feasible. For high-speed surface hardening, the power requirement may rise to 80 or 100 kW. per sq. in. without overheating the surface.

Owing to their non-magnetic character, the heating of non-ferrous metals in the lower temperature range is an entirely different proposition to the heating of ferrous materials. The ferro-magnetic character of the latter pulls in the lines of force surrounding the inductor, whereas for non-ferrous materials the strength of the inductor field has to be increased in order to achieve an equal heating effect. When a ferro-magnetic material has passed its

Curie point, the re-distribution of the lines of force produces an effect comparable with that obtained with a non-ferrous metal having equal resistivity.

ECONOMICS OF THE PROCESS

The initial cost of high frequency induction-heating equipment is extremely high in comparison with normal batch-type heat-treatment furnaces, and does not possess the flexibility of the latter. Whereas the conventional heat-treatment furnace is capable of heating any component which can be reasonably accommodated on its hearth, in induction heating, every article necessitates separate handling equipment, and where the part varies in section, several inductors may be required for one component. The considerable disparity between the cost of induction hardening machines and the cost of conventional equipment for similar applications must obviously be justified. The main advantages to be obtained are as follows :

(1) *High Thermal Efficiency.*—Generally 50 per cent. compared with between 4 and 8 per cent. for gas furnaces. The high thermal efficiency is due to the fact that heat is generated only in the component, and for rapid heating rates radiation losses are extremely small. In comparison, the losses in the conventional heat-treatment furnace are colossal having regard to the amount of brick-work to be heated, radiation from the furnace casing, and flue losses.

(2) *Heat Treatment in Production Line.*—Disposition of the hardening machine in the actual production line considerably reduces handling costs, eliminates internal transport and makes batching unnecessary.

(3) *Absence of Scale.* Cleaning after heat-treatment is rendered unnecessary when the heating rates are high. In the case of skin hardening of ferrous articles, the only evidence of the heating operation is a very slight surface discolouration.

(4) *Facility for Local Heating.*—No other method of heating enables the heating effect to be so localised, thus reducing fuel costs. A further advantage is where an excessive distribution of heat would result in a weakening of the structure, a typical example being the brazing of high strength steels.

Many claims have been put forward that induction heating eliminates distortion, but there is little practical foundation for such a claim. In the case of skin hardening, distortion is generally of the same order as that obtained in the conventional case-hardening process, although it is highly probable that hardening machines built with the necessary degree of precision would considerably reduce this trouble. Distortion usually results from non-uniform heating effects and lack of uniformity in quenching, and it is for this reason that the work is often spun in the inductor.

The comparative costs for skin hardening by high frequency induction heating and case-hardening methods for a motor car gudgeon pin, may be of interest. By the induction method the cost is 0.03d. inclusive of fuel and labour, compared with 0.50d. for case-hardening. Against this economy must be off-set the increased cost of a medium-carbon steel compared with a low-carbon steel, and also the higher maintenance cost of the high frequency equipment. Taking all contingencies into consideration, high frequency hardening shows a saving over the older methods of treatment, and it is a process which will be increasingly adopted as prejudice against its mysteries are overcome.

LOW HARDNESS ON SKIN HARDENING

The first requisite for adequate hardness, by which is generally meant a diamond hardness number in excess of 700, is a sufficiently high carbon content. It is possible under optimum conditions to achieve this hardness with a carbon content as low as 0.30 per cent., but generally speaking the carbon content will need to exceed 0.35 per cent. Where design of the part ensures uniformity of stress gradient, the carbon content should preferably be between 0.45 and 0.50 per cent.

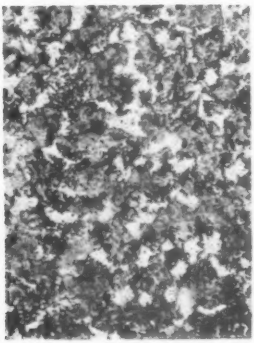

FIG. 9

Having established the necessary carbon range for any given component, low hardness is the result of incomplete dispersion os the carbon during the heating cycle. A zone of low hardness if shown in Fig. 9. For this reason it is more convenient to have the steel in the hardened-and-tempered condition although, obviously, such treatment prior to induction hardening will considerably reduce the economies of the process as compared with normal case-hardening. The rate of carbide dispersion during heating is

obviously a function of the distance over which the carbon atoms must travel to become uniformly dispersed. It is for this reason that the hardened or tempered or sorbitic state is the more desirable.

If the material is used in the normalised or the hot-rolled state, the carbon is contained in the grains of pearlite which are surrounded by a network of carbon-free ferrite. On heating, the carbide in the pearlite grains is dissolved, and in order to achieve uniform carbon distribution throughout the matrix the carbon atoms have to migrate across the ferrite network. The speed of migration is a function of both time and temperature. Generally speaking, therefore, if it is desired to achieve a similar surface hardness with steel of a given carbon content, in the sorbitised and the normalised state the latter will have to be treated either for a slightly longer period or for a similar period at a somewhat higher temperature. There need be no concern that a longer heating time will cause undesirable effects as the result of grain growth.

A further way in which high hardness in a normalised steel can be achieved, is to employ two-stage heating. The first stage of heating effects a refinement in the surface zone, and reduces the distance over which the carbon atoms have to travel. The structure of a normalised steel which has received the two-stage treatment is shown in Fig. 10.

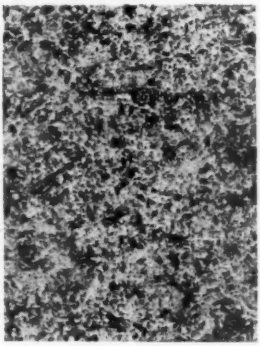

FIG. 10

CRACKING This mainly results from excessive localised stresses due to the volume change which occurs when the material is hardened by quenching. The cracks may not develop in the actual quenching operation, but may occur some time later. They are generally to be found on parts which are locally hardened, as distinct from parts which are hardened over their entire surface.

An example of this type of cracking, in a starter ring, is given in Fig. 11, in which only the clash face is hardened. An exceptionally complicated stress pattern is set up in the hardened zone, and hardening cracks develop along the line of maximum tensile stress. The degree of stress in such a part can be minimised by reducing the carbon content of the steel used, but a balance has to be struck so that a satisfactory hardness is obtained by the treatment, associated with residual stresses below the limiting stress at which cracking is likely to occur. Such a balance can only be determined by trial and error. A further cause of cracking is dirty steel, or steel containing an excessive amount of non-metallic matter in the form of slag or oxide streaks which normally appear as lines during machining operations. Surface interruptions such as these are a frequent cause of hardening cracks, as also are sub-microscopic laps.

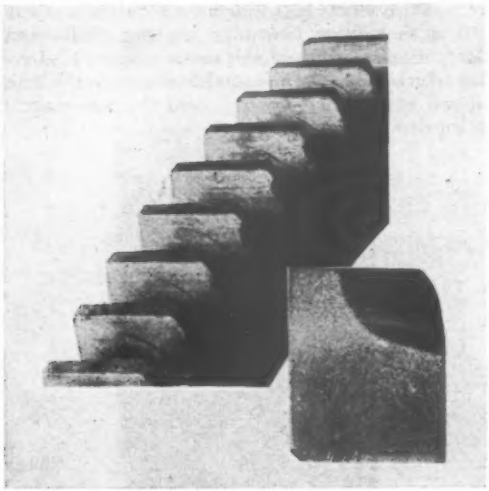

FIG. 11

STREAKY HEATING

This is a phenomenon quite well known to high-frequency induction heating experts, and yet extremely difficult of explanation. A typical example of streaky heating is shown in the microstructure, Fig. 12. It can be stated briefly to be due to unstable conditions due to non-uniform field strength below the Curie point. The remedy is to harden the

workpiece by scanning with a single-turn inductor, but even so streaky heating may occur due to instability of the generator.

FUSION OF SURFACE

There can obviously be only one cause of this effect, this being over-heating. Over-heating is due either to heating for too long a period at high power density, or the employment of excessive power density. In skin hardening, the optimum power density is that at which the rate of heating is greater than the rate of thermal conduction, but yet insufficient to cause fusion of the surface. In the progressive method of hardening, the power density is of such a value that if the flow of the work is interrupted, instantaneous surface fusion occurs. For through heating, the power density has to be very much lower, in order that the heat developed in the surface layers can be conducted to the cold interior without the surface skin exceeding a desirable temperature.

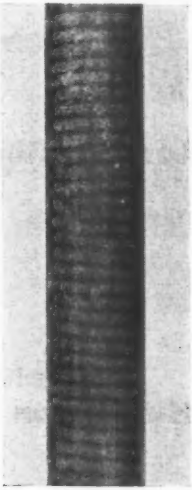

FIG. 12

UNSATISFACTORY PENETRATION IN BRAZING

Unsatisfactory penetration of the joint is due either to excessive or insufficient clearance, or to insufficient time having been allowed for the locally induced heat to be dissipated throughout the joint area.

CONCLUSIONS

This article has discussed the practical applications of the high frequency method of heating, giving illustrations of actual production applications as distinct from laboratory experiments. It is a method of heating which is bound to find increasing use as experience in its application grows, but should be approached with caution, believing only that which can be proved to be a practical proposition. In seeking to apply the process, it should be stressed that maintenance and repair of the generating plant should be the responsibility of the maintenance department. Such repairs are generally of a minor character, and, in the case of the thermionic generator, require only a brief interruption of production.

In conclusion, the author wishes to thank the directors of Morris Motors Ltd., for permission to publish this article, and also various members of the staff of the central laboratories of the Nuffield organisation, in particular Mr. J. H. Bridle, for advice on electrical matters, and Mr. L. W. Harris, for the preparation of the illustrations.

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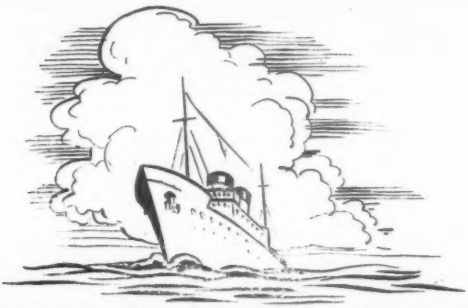

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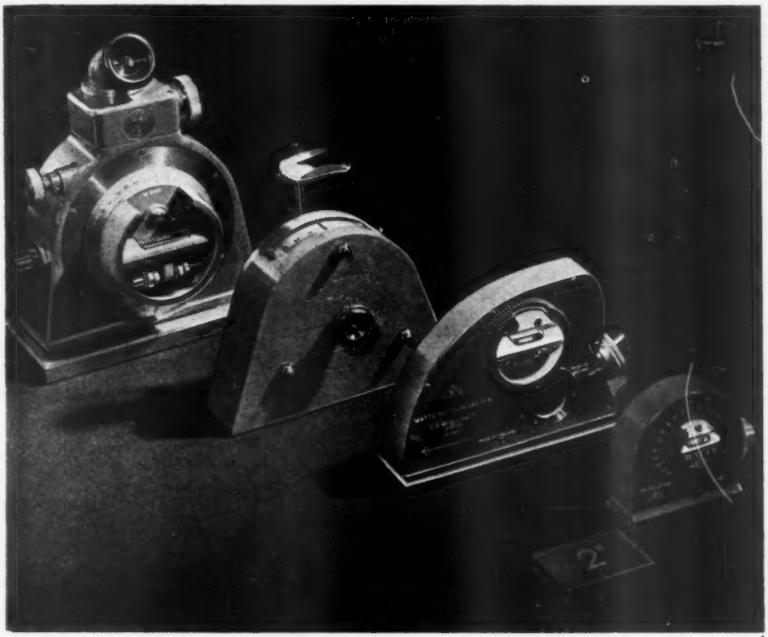

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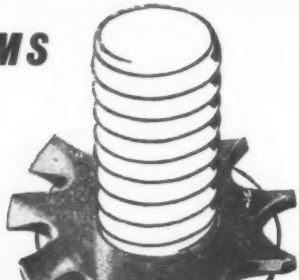


Vibration proof, speedier and cost-reducing, G.K.N.'s Sems Fastener Units are delivered with the correct size and type of lockwasher already assembled on the screws. The washers are free to turn but can't come off. The units avoid handling and loss of washers — make for easy driving — make completely secure fastenings and simplify stock control. As Sems save time they also save money — time after time after time.

GET IN TOUCH WITH GKN

GUEST KEEN & NETTLEFOLDS (MIDLANDS) LIMITED
Screw Division: Box 24, Heath Street, Birmingham 18

S/SEU/2855

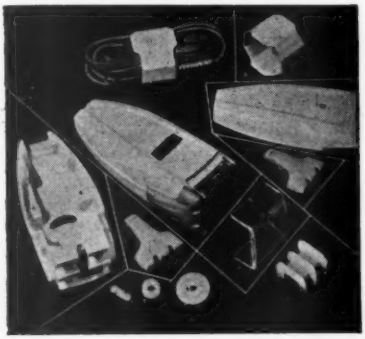
ask your moulder...

This is the second in a series of announcements designed to assist Buyers in purchasing plastics—moulded articles or components.

One point on which you will need assurance — all the more if you are a large consumer with a number of moulding contracts — will be the versatility of your moulder. The range of his equipment will interest you, not only because his ability to produce a good job at a good price may be influenced by it, *but also because it is a much simpler matter for you to deal with one moulder than with several.*

The question is tied up with the choice of materials, the nature of your jobs, the volume of output required. Can he, you ask, mould high-quality articles, large *and* small? . . . can he mould in both thermosetting *and* thermoplastic materials?

Many jobs could be carried out in any one of a number of materials. Others call for the use of different materials for different components. To a large extent your choice must depend on your moulder's advice. If it is to be worth having he must have had experience of all kinds of moulding materials and ideally he should be in a position to follow it himself — to mould almost any mouldable material. Check up on this essential aspect of service and choose only a moulder so experienced and equipped that he can offer you unbiased advice in this as in every other sphere of his work.



The assembly illustrated entails the moulding (in quantity) of eleven components in no less than seven different plastic materials, both thermosetting and thermoplastic. The customer found it a great convenience to be able to employ one experienced and versatile firm for the multiple job.
Mouldings by The Streetly Manufacturing Co. Ltd. for Remington Rand Ltd.

If in doubt, ask **STREETLY**

The Streetly Manufacturing Co. Ltd. makes mouldings in thermosetting or thermoplastic materials and specialises in long runs of highest quality mouldings. A h gh percentage of its regular output is of mouldings for manufacturers of electrical equipment and accessories. If you have a moulding job in view, call in Streetly for practical, down-to-earth advice.

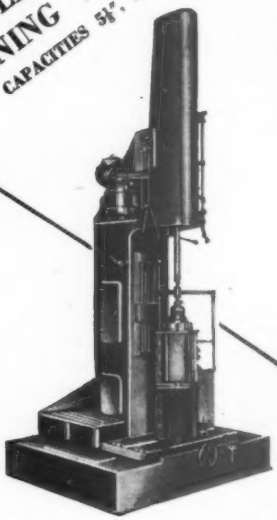
THE STREETLY MANUFACTURING COMPANY LIMITED,
STREETLY, SUTTON COLDFIELD, NR. BIRMINGHAM.
TELEPHONE: STREETLY 78411 TELEGRAMS: BANG STREETLY

B·I·P GROUP

CIMOF

HYDRAULIC LAPPING AND HONING MACHINES

CAPACITIES 5½", 7½", 9½", 12"



Controlled dwell to eliminate taper and ovality • Hydraulic reciprocating movement with infinitely variable speed • Rapid fine adjustment of stroke for blind holes • Adaptable for multi-station fixtures

EARLY DELIVERY

As sole British Agents we shall be pleased to advise on your problems.

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STAINES MIDDLESEX

AGENCIES DIVISION:
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Phone: SLOANE 2272 (3 lines)

Knurled micrometer ring for quick and accurate adjustment. Patented release for withdrawal without loss of adjustment.

FOR THESE AND OTHER MACHINES

CIMOF HONES

An Announcement . .

DUREX ABRASIVES LTD wish to announce that as from June 14th, 1951, the name of the Company has been changed and is now the MINNESOTA MINING & MANUFACTURING COMPANY LTD. The range will in future bear the name of the new Brand-titles listed below, and the kind co-operation of the Trade in the use of the new brand names would be appreciated in future ordering.

Existing high standards in the quality of the products will be maintained, the change is in name only.

CHANGE OF NAME

"Durexite" Cloth	to	'Three-M-ite" Cloth
"Durexite" Cloth Economy Rolls and Sheets	to	"Three-M-ite" Cloth Elek-tro-cut
"Hydro-Durexite" Cloth	to	"Wetordry Three-M-ite" Cloth
"Durexite" Fibre Combination Discs	to	3M Discs Type A
"Durexite" Resin Bond Discs	to	3M Discs Type C
"Durexsil" Fibre Combination Discs	to	"Tri-M-ite" Fibre Combination Discs
"Hydro-Durexsil" Cloth	to	"Wetordry Tri-M-ite" Cloth
"Hydro-Durexsil" Paper	to	"Wetordry Tri-M-ite" Paper
"Durexsil" Paper	to	"Tri-M-ite" Paper
"Durexsil" Cloth	to	"Tri-M-ite" Cloth
"Durexalo" Paper	to	3M Production Paper

Distributive Arrangements unchanged. Supplies obtainable from former Durex Brand Distributors.

CHARLES CHURCHILL & CO. LTD., Birmingham and Branches

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of all kinds

Up-to-date shops specially laid out and equipped for making, on a production basis, every type of precision ground gauges; limit snap, form, calliper, taper and special purpose gauge, as well as jigs and fixtures of all kinds, press tools, moulds and special purpose machines. Highest class workmanship and accuracy guaranteed.

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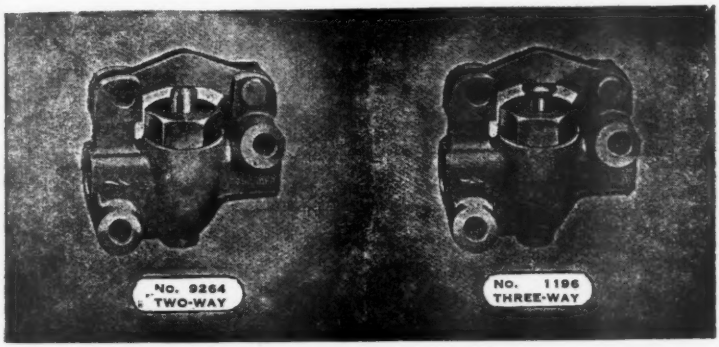

Saving machine operators' time — automatically

On many machines it is possible to use an air blast to eject finished work or carry out some similar operation. Where these air blasts are timed to conform to the cycle of operations of the machine the automatic motion speeds output and lessens fatigue of the operator. Schrader Blow Valves make things easier for the operator—and the Production Manager.

No. 9264 Two-Way BLOW VALVE
For automatic tripping providing a timed air blast. Shuts immediately upon release of the tripping pressure. Correctly timed intermittent air blasts eliminate wastage of air.

No. 1196 Three-Way BLOW VALVE
Same features as the two-way valve plus an exhaust port. This releases, through the port in the valve plunger, the compressed air passed to a cylinder or other confined area.

Schrader

AIR CONTROL EQUIPMENT

increases output and reduces production costs

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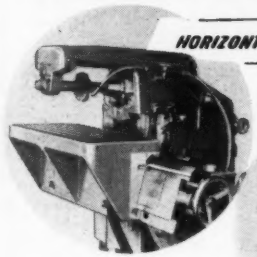
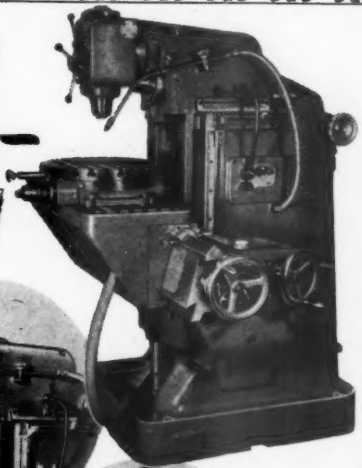
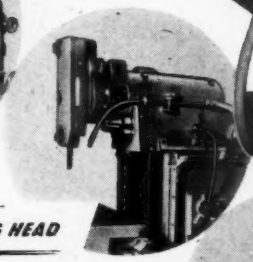
A REALLY VERSATILE MILLER—

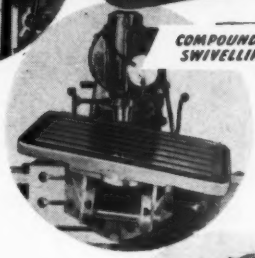


HORIZONTAL MILLING





SLOTTING HEAD



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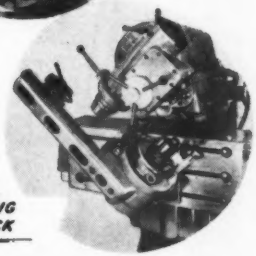
WITH THE SPEED, POWER AND ACCURACY FOR TOOLROOM AND PRODUCTION WORK —ACCURATE ENOUGH FOR JIG BORING!

A truly versatile machine, built with unusual accuracy and with special attention to speedy and easy operation.

Note the special attachments which permit the rapid changing over from one operation to another without altering work position. Single lever control for all power feed motions. Automatic stops with precision setting. Large diameter micrometer dials.



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ENSURES HIGH PRECISION ON AIRCRAFT WORK
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We build plain, universal and fine grinding machines, as well as surface grinders in a wide range of sizes. Let us show you just where and how PRECIMAX grinders could improve accuracy, finish and output on your own work.
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Of the 2,500 different species of snakes — the Cobra is the most poisonous. The King Cobra or Hamadryad reaches as much as 16 ft. in length and has a nasty habit of erecting his hood when annoyed. And they don't *sting with their tongues — these are merely for touch and smell. The poison comes from hollow teeth — nice sharp teeth — teeth in fact which are perfectly designed for the job.*

perfectly designed to do the job

The Wild-Barfield Electrode Salt Bath also does the job perfectly. Using different salts for different ranges, temperatures can be maintained between 550°C. and 1350°C. In the high temperature ranges greater rapidity of heating is achieved than by any other method, and the protective nature of the salt ensures a clean finish and freedom from decarburisation. Perfect in fact for pre-heating, hardening, quenching and secondary hardening of high-speed steels ; hardening carbon and low alloy steels ; cyanide hardening ; brazing etc.

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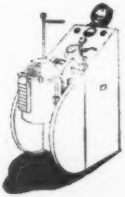

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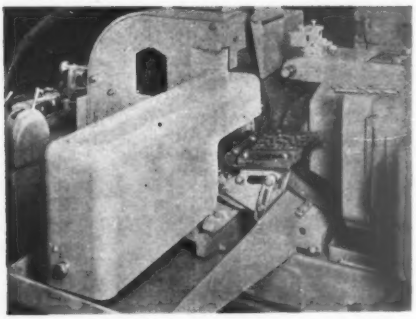

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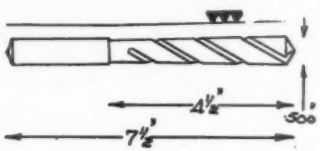

Twist drill makers in a keenly-competitive industry require high production machines in all stages of the manufacture of their product.

PIECE:	Jobber drill.
MATERIAL:	High-speed steel.
MACHINE:	Scrivener No. 2 controlled-cycle Automatic
OPERATION:	Plunge-grind shank and back taper on fluted portion.
STOCK REMOVAL:	.008"
TOLERANCES:	Size, ± .0005"
PRODUCTION:	Up to 600 per hour.

ARTHUR SCRIVENER, LTD., BIRMINGHAM, 24
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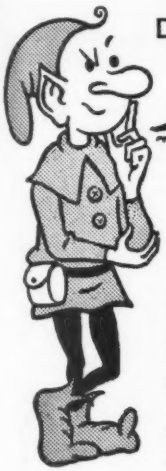

DAN DWARF ASKS —

Are you a Model Employer?

Most employers would answer this question with an emphatic affirmative. Conditions have vastly improved since the days of cut-throat competition and sweated labour. Social welfare, sickroom facilities, and joint production committees are now common. But the model employer had these facilities long before they became general. He knows that he gets more production out of healthy workers, so he is constantly receptive to new ideas and equipment which will further this end. Attachments such as the Spenstead Dwarf Dust Collecting Unit, for instance, which when coupled to a grinding machine absorbs all the flying particles of dust before they can settle on the operator's throat and lungs

He doesn't wait until he is compelled to comply with Factory Regulations, but installs them for the benefit of his workers now.

The compact and efficient **SPENSTEAD DWARF DUST COLLECTOR** embodying ½ h.p. motor-driven fan and two-stage collection.

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VSG'

Registered Trade Mark

The illustration shows the S.H.8/10 Injection Moulding Machine manufactured by R. H. Windsor Ltd. Equipped with a Size 3/2000 "VSG" Auto Pump, this machine is capable of 200 shots per hour.

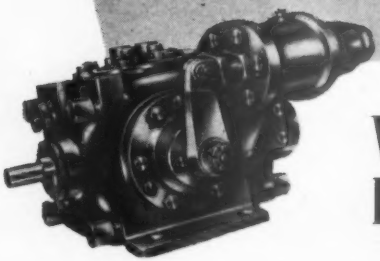
"VSG" Variable Delivery Pumps are axial piston pumps of high volumetric efficiency. They are made in seven sizes delivering from 5 to 340 gallons per minute and in three pressure ranges, namely 1000, 2000 & 3000 p.s.i.

Two main types are available.

The manually controlled variable delivery pump will give constant delivery for any given setting, irrespective of pressure variations.

With the auto-pump, delivery is automatically regulated by the pressure in the hydraulic system.

If you are interested in either of these two types why not ask for full particulars?



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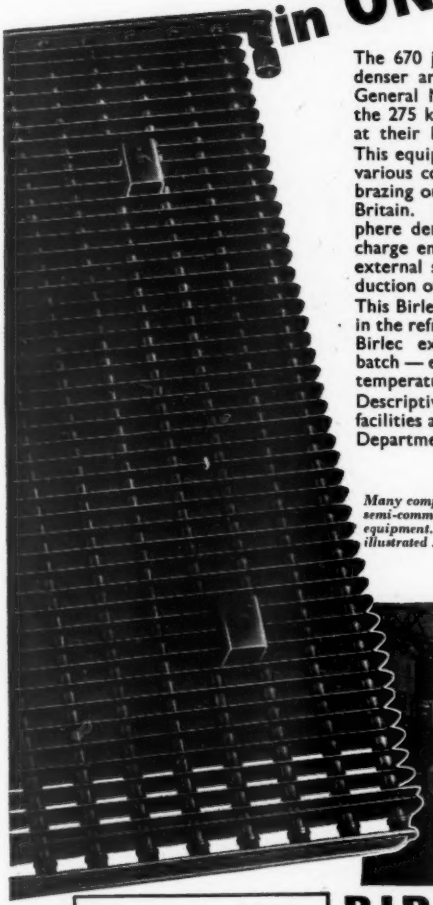
brazing 670 joints in ONE operation

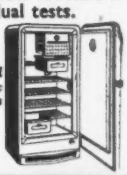


The 670 joints of this intricate refrigerator condenser are brazed by the Frigidaire Division of General Motors Limited in one passage through the 275 kW Birlec roller hearth furnace installed at their London factory.

This equipment handles approximately 1200 lb. of various components per hour, the largest copper brazing output of any furnace equipment in Great Britain. A precisely controlled reducing atmosphere derived from town's gas ensures that the charge emerges completely free from internal or external scaling — an essential factor in the production of refrigeration equipment.

This Birlec furnace is an example of many installed in the refrigerator industry and typifies, moreover, Birlec experience in building continuous — or batch — equipment for large outputs at high temperatures.

Descriptive literature will be sent on request and facilities are available at the Birlec Heat Treatment Department for carrying out individual tests.



Many components of Frigidaire domestic and semi-commercial units are brazed in Birlec equipment. A 7·3 cu. ft. refrigerator is illustrated . . .

GAS AND ELECTRIC FURNACES

SM/B.173c

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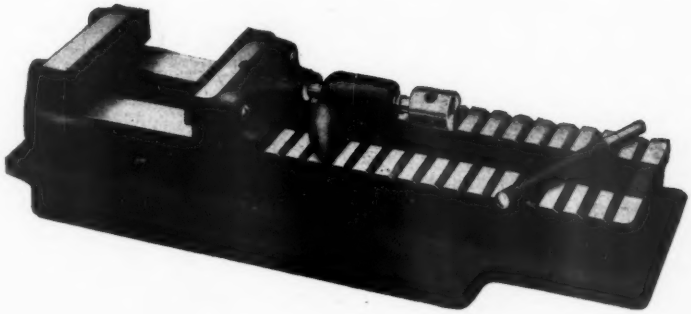

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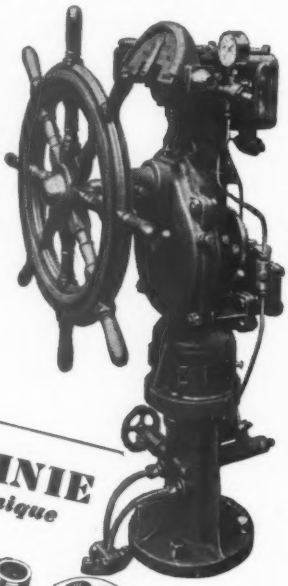
Every helmsman knows Donkin Hydraulic Steering Gear, and every Marine Engineer knows McKechnie Manganese Bronze—which is used extensively by Donkin because of its high tensile qualities. The use of extruded brass and bronze bar is constantly increasing—a "regular" metal and lower machining costs have a distinct appeal to Captains of Industry who are successfully steering into the Trade Winds.

BRASS & BRONZE EXTRUSIONS & STAMPINGS.



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M-W.100R

BARBER - COLMAN

combination sharpening machine

For controlled sharpening of hobs milling cutters and reamers

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GRINDS WET OR DRY TO BETTER FINISHES

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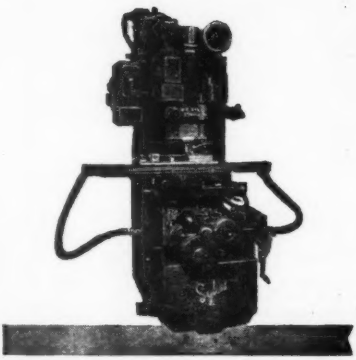
HANDLES SHORT LEADS AND SMALL DIAMETERS

REGRINDS TO NEW DESIGN SPECIFICATIONS

CONTROLS DIAMETER SIZE AND PROFILE

...on your production programme?



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For Gears up to 14" dia. and Racks up to 36" long

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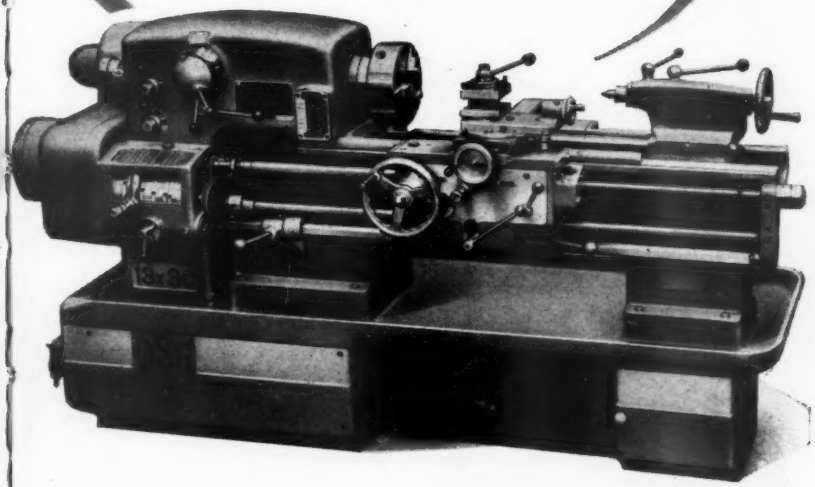

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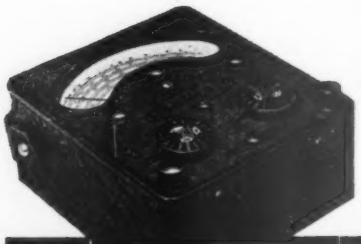

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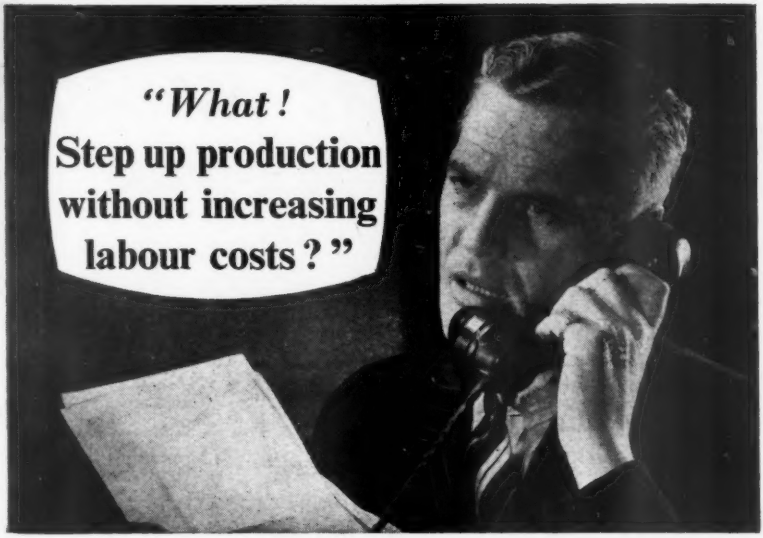

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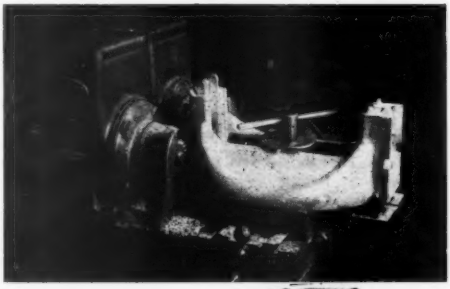

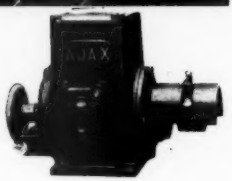

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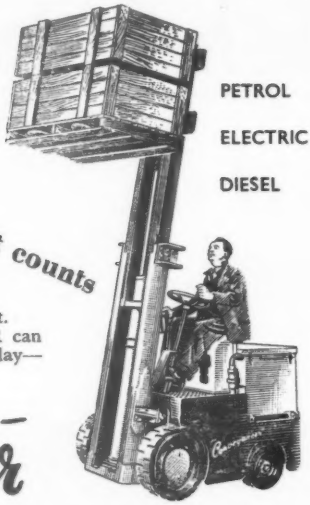

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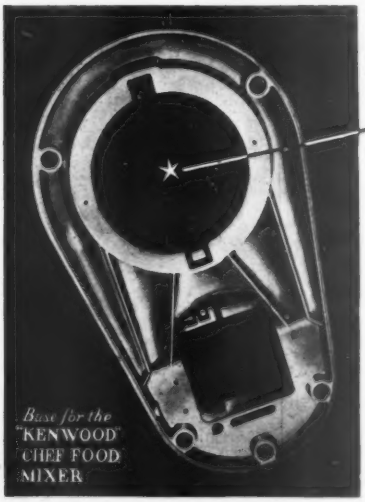

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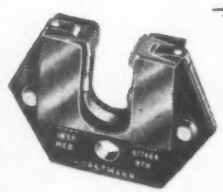

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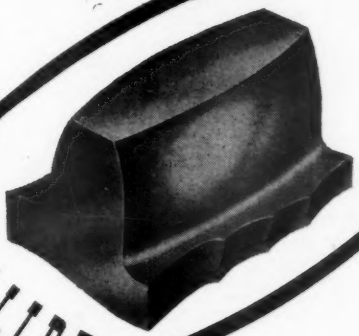

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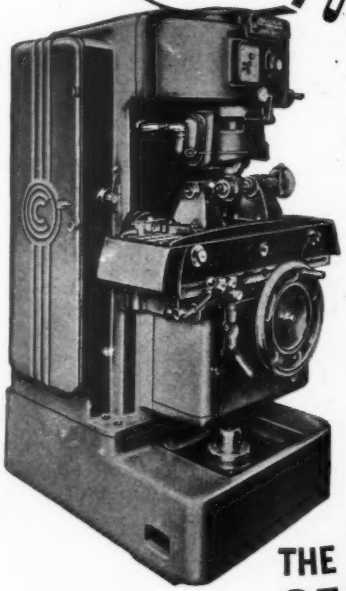

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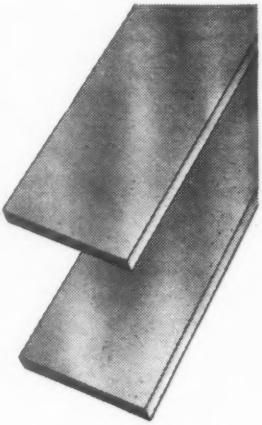

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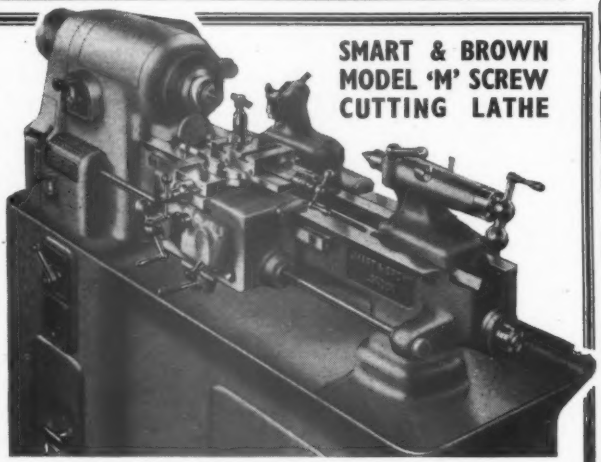

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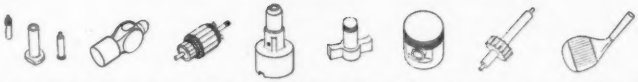

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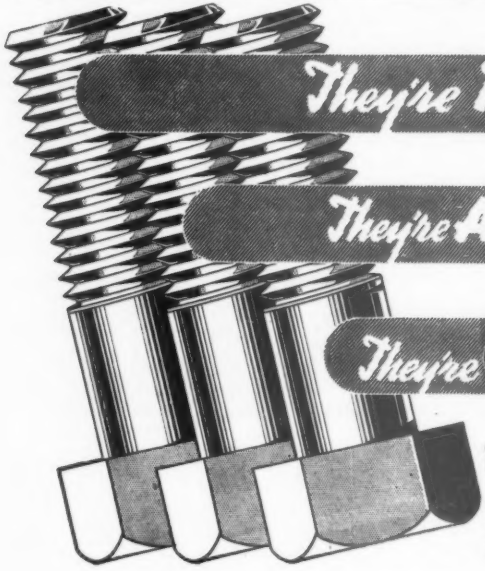

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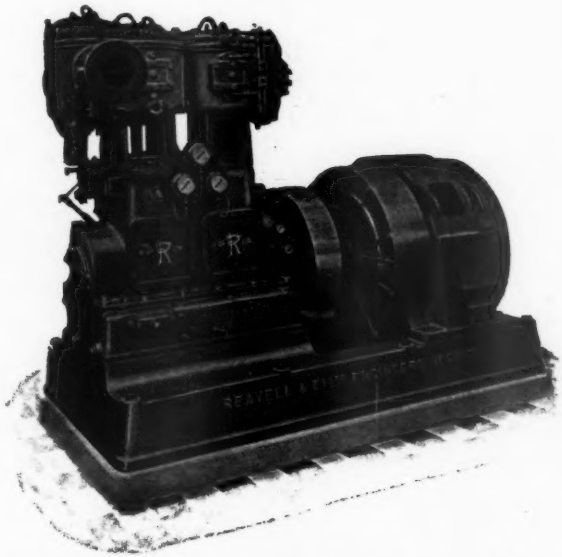

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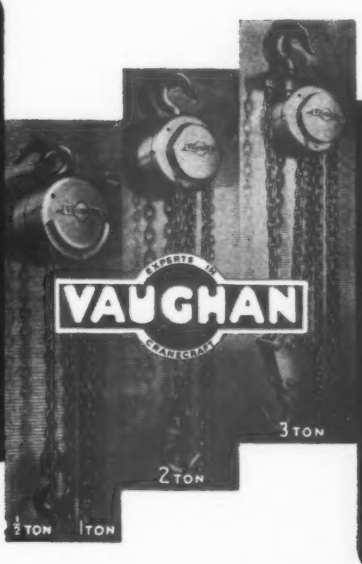

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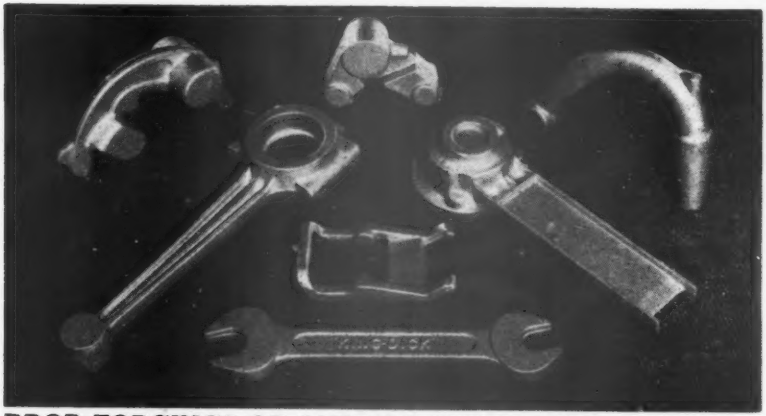

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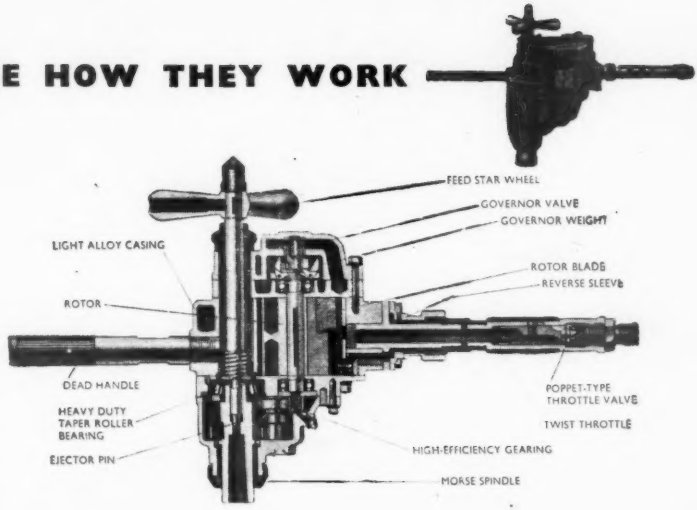

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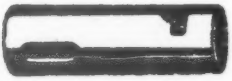

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